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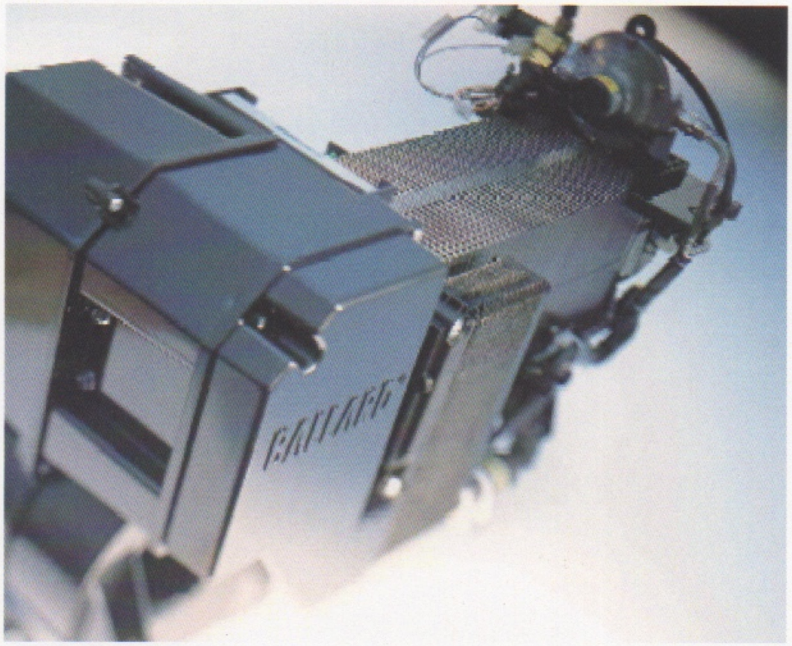
Ballard Power Systems

NEXA™ POWER MODULE INSTALLATION MANUAL

Part A – Installation Manual

Part B – Integration Guide



Nexa™ (310-0027) Power Module Installation Manual

5,000,000 Series PBS

Proprietary Notice/Declaration
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ii. Certification

The Nexa™ power module is UL and CSA approved.

iii. Disclaimer

This manual incorporates safety guidelines and recommendations. However, it is not intended to cover all situations. It is the responsibility of the customer to meet all local safety requirements and to ensure safety during operation, maintenance and storage of the Nexa™ power module.

Although all efforts have been made to ensure the accuracy and completeness of the information contained in this document, Ballard reserves the right to change the information at any time and assumes no liability for its accuracy.

iv. Glossary

AC	Alternating Current
BAR g	Bar gauge pressure
Cold Start	A start up attempt when Nexa™ has reached a steady state at ambient temperature
CVC	Cell Voltage Checking system
DBA	Decibel
DC	Direct Current
Fuel cell stack	Individual fuel cells combined
Indoors	Inside a building or shelter where natural airflow is limited or enhanced by forced ventilation systems
kW	Kilowatt
kPa(g)	Kilo-Pascals gauge pressure
LPH	Litres per hour
MTBF	Mean Time Between Failure
OEM	Original Equipment Manufacturer
Outdoors	Location where natural airflow is not restricted and where Nexa™ is sufficiently protected by an outer enclosure against bad weather. Never operate Nexa™ in wet, freezing or marine conditions. Nexa™ must always be protected from wind, blowing sand and dust.
PSIG	Pounds per square inch – gauge pressure
SCFM	Standard cubic feet per minute
SLPM	Standard litre per minute, measured at 1 atm, 0°C
UPS	Uninterrupted power supply
V	Volt
VDC	Voltage, Direct Current
BOL	Beginning of Life
EOL	End of Life

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1 Introduction

The Nexa™ power module is a small, low maintenance and fully automated fuel cell system designed to be integrated into products for portable and back-up power markets. It is ready to integrate into a variety of products for household and commercial use. The Nexa™ power module is not designed for medical applications or mission critical use.

The Nexa™ system provides up to 1200 watts of unregulated DC power at a nominal output voltage of 26 VDC. With the use of an external fuel supply, operation is continuous, limited only by the amount of fuel storage. Using hydrogen fuel, the Nexa™ module is extremely quiet and produces zero harmful emissions, permitting indoor operations.

This manual describes the Nexa™ system design and operation. It provides technical product specifications, performance characteristics and interface requirements for installation and operation. Important safety information is also included. Please review the contents of this manual before operating your Nexa™ module and contact Ballard Customer Service if you have any questions.

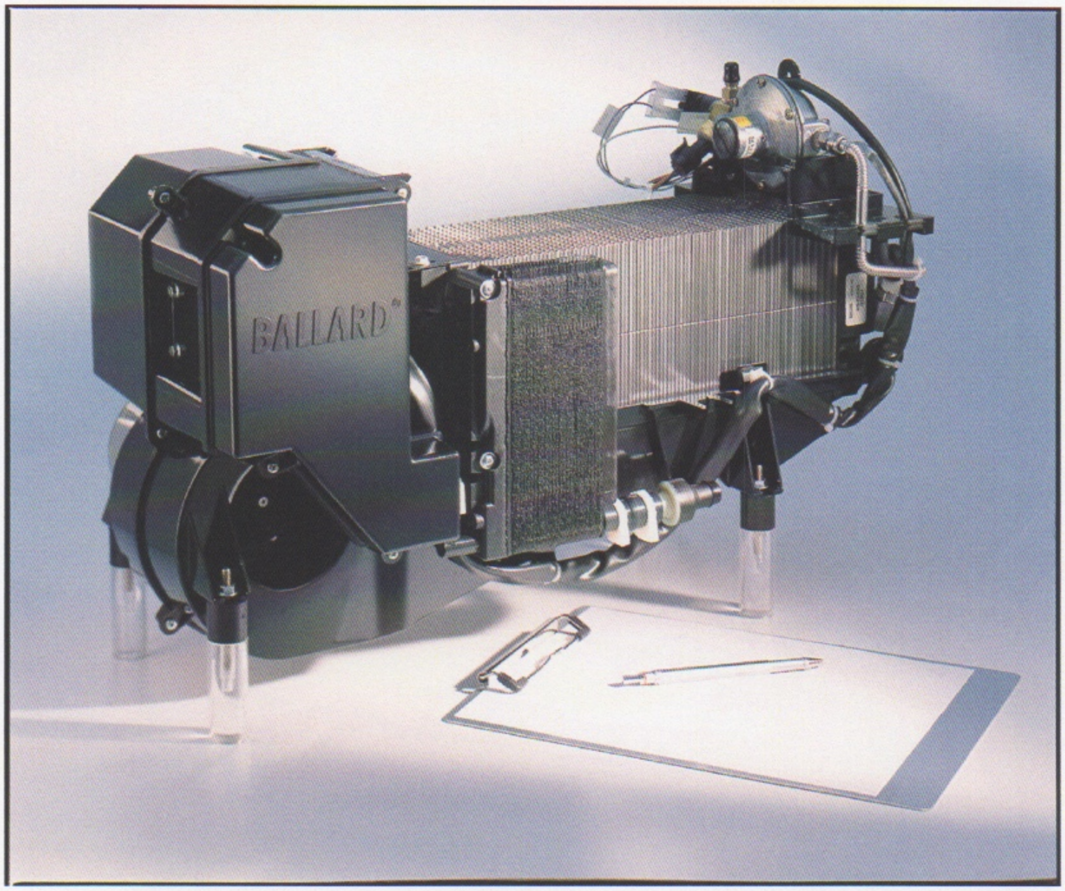

Figure 1: The Nexa™ Power Module

1.1 General Description

The Nexa™ power module is a fully integrated system that produces unregulated DC power from a supply of hydrogen and air. It contains a BALLARD® fuel cell stack, as well as all the ancillary equipment necessary for fuel cell operation. Ancillary subsystems include hydrogen delivery, oxidant air supply and cooling air supply. Onboard sensors monitor system performance and the control board and microprocessor fully automate operation. The Nexa™ system also incorporates operational safety systems for indoor operation.

Figure 2 illustrates the Nexa™ system schematic. The diagram also shows the Nexa™ system boundary and important interface connections to the DC module. Hydrogen, oxidant air, and cooling air must be supplied to the unit, as shown in Figure 2. Exhaust air, product water and coolant exhaust is emitted. The Nexa™ power module produces unregulated DC power for interfacing with external power conditioning equipment. Battery power must be supplied for start up and shut down requirements. Finally, a communications interface must be provided to the Nexa™ unit for providing start/stop signals and for receiving serial port communications.

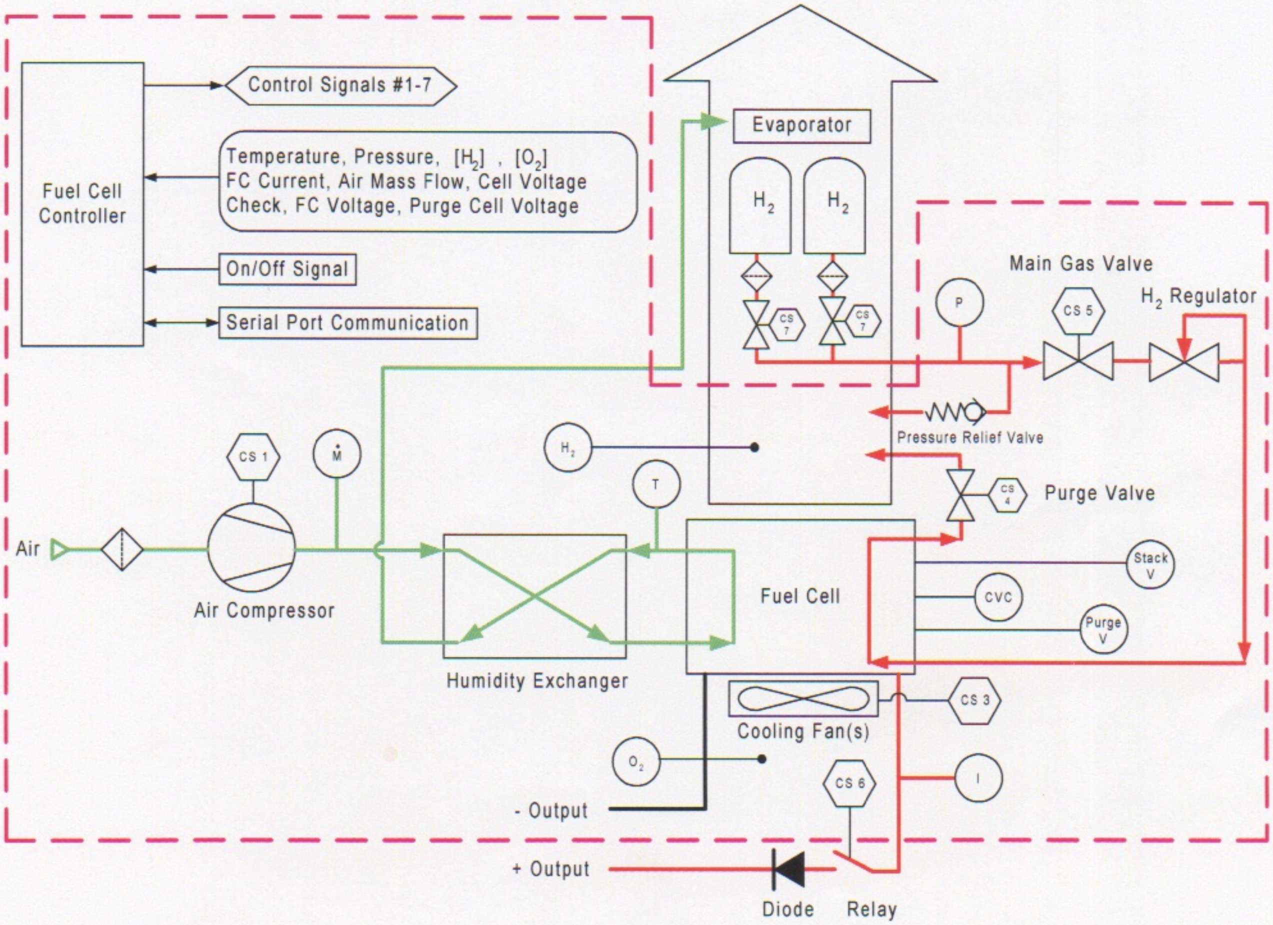

Figure 2: Nexa™ System Schematic

1.2 Fuel Cell Principles

The fundamental component of the Ballard® fuel cell consists of two electrodes, the anode and the cathode, separated by a polymer membrane electrolyte. Each of the electrodes is coated on one side with a thin platinum catalyst layer. The electrodes, catalyst and membrane together form the membrane electrode assembly. A single fuel cell consists of a membrane electrode assembly and two flow field plates, as shown in Figure 3.

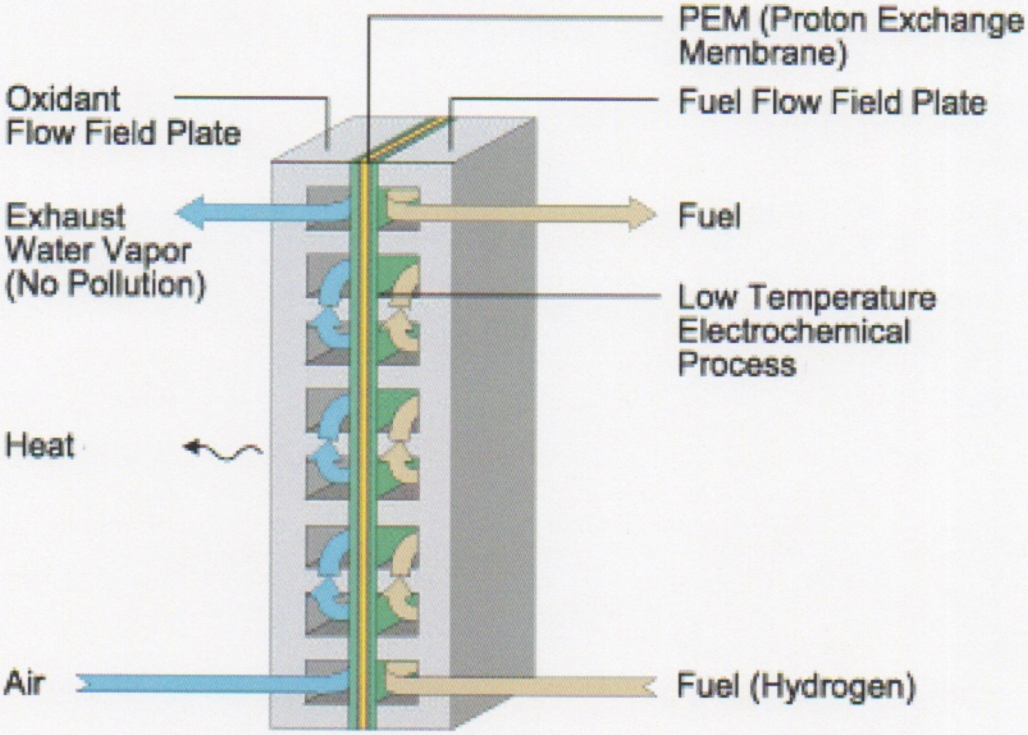
PEM (Proton Exchange Membrane)
Oxidant Flow Field Plate
Fuel Flow Field Plate
Exhaust Water Vapor (No Pollution)
Fuel
Low Temperature Electrochemical Process
Heat
Air
Fuel (Hydrogen)

Figure 3: PEM Fuel Cell Principals

Gases (hydrogen and air) are supplied to the electrodes on either side of the membrane through channels formed in the flow field plates. Hydrogen flows through the channels to the anode where the platinum catalyst promotes its separation into protons and electrons. The free electrons are conducted in the form of usable electric current through an external circuit, while the protons migrate through the membrane electrolyte to the cathode. At the cathode, oxygen from the air, electrons from the external circuit and protons combine to form pure water and heat.

Individual fuel cells are combined into a fuel cell stack to provide the required electrical power. A single fuel cell produces about 1 volt at open circuit and about 0.6 volts at full load. Cells are stacked together in series to provide the required output voltage. In turn, the output current of a fuel cell is proportional to its active area. Consequently, the fuel cell stack geometry can be tailored to provide the desired output voltage, current and power characteristics.

1.3 Fuel Cell Stack

PEM fuel cell stacks produce unregulated DC power from hydrogen and air. Water and heat are the only by-products of the reaction. The PEM fuel cell stack incorporated into the Nexa™ system has been developed with a number of important attributes for the portable power market. First, the Nexa™ fuel cell stack operates at low pressure, minimising parasitic losses, reducing noise, and enhancing system reliability. Second, the Nexa™ fuel cell stack architecture does not require external fuel humidification. Furthermore, this fuel cell stack is air-cooled, which further simplifies the overall system design.

The Nexa™ fuel cell stack has been sized to provide 1.2 kW of net output power. The output voltage varies with power, ranging from about 43 V at system idle to about 26 V at full load. During Nexa™ system operation, the fuel cell stack voltage is monitored for diagnostic, control and safety purposes, as shown in Figure 2. In addition, a cell voltage checker (CVC) system monitors the performance of individual cell pairs and detects the presence of a poor cell. The Nexa™ unit will shut down if a cell failure or a potentially unsafe condition is detected in the fuel cell stack.

1.4 Hydrogen System

The Nexa™ power module operates on pure, dry hydrogen from any suitable source. The fuel-supply system, as shown in Figure 2, monitors and regulates the supply of hydrogen to the fuel cell stack. The fuel supply subsystem is comprised of the following components:

- A pressure transducer monitors fuel delivery conditions to ensure an adequate fuel supply is present for Nexa™ system operation.
- A pressure relief valve protects downstream components from over-pressure conditions.
- A solenoid valve provides isolation from and the fuel supply during shut down.
- A pressure regulator maintains appropriate hydrogen supply pressure to the fuel cells.
- A hydrogen leak detector monitors for hydrogen levels near the fuel delivery subassembly. Warning and shut down alarms are implemented for product safety.

The fuel cell stack is pressurised with hydrogen during operation. The regulator assembly continually replenishes hydrogen, which is consumed in the fuel cell reaction. Nitrogen and product water in the air stream slowly migrates across the fuel cell membranes and gradually accumulates in the hydrogen stream. The accumulation of nitrogen and water in the anode results in the steady decrease in performance of certain key fuel cells, which are termed "purge cells". In response to the purge cell voltage, a hydrogen purge valve at the stack outlet is periodically opened to flush out inert constituents in the anode and restore performance.

Only a small amount of hydrogen purges from the system, less than one percent of the overall fuel consumption rate. Purged hydrogen is discharged into the cooling air stream before it leaves the Nexa™ system, as shown in Figure 2. Hydrogen quickly diffuses into the cooling air stream and is diluted to levels many times less than the lower flammability limit. The hydrogen leak detector, situated in the cooling air exhaust, ensures that flammable limits are not reached. This feature permits safe, indoor operation of the Nexa™ power module.

1.5 Oxidant Air System

A small compressor provides excess oxidant air to the fuel cell stack in order to sustain the fuel cell reaction. An intake filter protects the compressor and downstream components from particulate in the surrounding air. The compressor speed is adjusted to suit the current demand of the fuel cell stack. Larger currents require more airflow. A downstream sensor measures air mass flow rate and controls fine-tune the compressor speed to suit the required current demand.

Oxidant air is humidified before reaching the fuel cells to maintain membrane saturation and prolong fuel cell lifetime. A humidity exchanger transfers both fuel cell product water and heat from the wet cathode outlet to the dry incoming air.

Excess product water is discharged from the system, as both liquid and vapour, in the oxidant air exhaust. Product water must be managed through end-use integration design. Excess water may be evaporated passively into the surrounding environment, as shown in Figure 2. Alternatively, product water can be drained and collected.

1.6 Cooling System

The Nexa™ fuel cell stack is air-cooled. A cooling fan located at the base of the unit blows air through vertical cooling channels in the fuel cell stack. The fuel cell operating temperature is maintained at 65°C by varying the speed of the cooling fan. The fuel cell stack temperature is measured at the cathode air exhaust, as shown in Figure 2.

Hot air from the cooling system may be used for thermal integration purposes. Heat rejected in the air can be used for integration with metal hydrides, for evolving hydrogen. Hot air may also be used for space heating in some cases.

The cooling system is also used to dilute hydrogen that is purposely purged from the Nexa™ module during normal operation. Hydrogen is released into the cooling air stream by way of the purge solenoid valve, as shown in Figure 2. The hydrogen quickly diffuses into the cooling air and is diluted to levels far below the Lower Flammability Limit (LFL) of hydrogen.[1] For safety, a hydrogen sensor is located within the cooling air outlet stream and provides feedback to the control system. The control system generates warning and alarm signals if the hydrogen concentration approaches 25% of the LFL.

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[1] The Lower Flammability Limit (LFL) of hydrogen is the smallest amount of hydrogen that will support a self-propagating flame when mixed with air and ignited. At concentrations less than the LFL, there is insufficient fuel present to support combustion. The LFL of hydrogen is 4% by volume.

1.7 Electronic Control System

Nexa™ system operation is automated by an electronic control system. The control board receives various input signals from onboard sensors. Input signals to the control board include: fuel cell stack temperature, hydrogen pressure, hydrogen leak concentrations, fuel cell stack current, air mass flow, fuel cell stack voltage and purge cell voltage. The status of the Cell Voltage Checker (CVC) system is also an input to the control board, presenting either a Pass or Fail result for the operational status of the stack. Finally, the ambient oxygen concentration is measured by an onboard sensor and sent to the controller, to ensure a safe operating environment is assured for the user.

Analogue and digital output control signals are issued from the control board to regulate system operation. Control commands are issued for opening and closing the hydrogen solenoid valve and purge valve of the Nexa™ module. The speed of the air compressor is varied based on current demand. The speed of the cooling fan is also controlled to regulate the fuel cell stack temperature. An external load relay is opened or closed by the Nexa™ control system for engaging or disengaging the fuel cell stack to external loads. The control system also issues a signal for opening and closing external solenoid valves, to isolate hydrogen storage tanks when the Nexa™ module is not in operation.

Communications to and from the end product are delivered through the Nexa™ control board. An on/off signal is issued to the fuel cell controller for starting or stopping the Nexa™ system. The controller communicates with external equipment using the RS-485 serial protocol. Transmitted data includes status and performance information. Received data includes operational commands for self-test and diagnostic purposes.

Unusual or unsafe operating conditions result in either a warning or alarm and automatic shutdown, depending on severity. During a warning, the Nexa™ power module continues to operate and the controller attempts to remedy the condition if possible. During an alarm, the controller initiates a controlled shutdown sequence. Removing the external on/off signal will reset most alarms. Once reset, the Nexa™ power module can then be restarted. For safety reasons, certain alarms can only be reset by Ballard Customer Service. These non-restartable faults include hydrogen leaks, self-test faults and software faults.

When energised, the controller continually transmits data approximately once every 200 ms. Transmitted data includes system status codes, warning codes and alarm codes, as indicated in Table 1. In addition, fuel cell system operating parameters are provided through the serial port for monitoring and display purposes. The data bytes provide floating-point signal values in engineering units for selected transducers, as indicated in Table 2.

Status Codes	Warning Codes*	Alarm (Failure) Codes
Standby Starting Running Warning Normal Shut-down Failure Shut-down Non-Restartable	No Warnings High Fuel Cell Stack Temperature Warning Low Fuel Cell Stack Voltage Warning High Fuel Cell Stack Current Warning Low Fuel Pressure Warning Fuel Leak Warning Low Oxygen Concentration Warning Low Purge Cell Voltage Warning *Multiple warnings are indicated concurrently	Normal Operation High Fuel Cell Stack Temperature Low Fuel Cell Stack Voltage High Fuel Cell Stack Current Low Cell Voltage Low Fuel Pressure Fuel Leak Detected Low Oxygen Concentration Low Ambient Temperature Low Purge Cell Voltage Low Battery Voltage Startup Time Expired Self Test Fault Software Fault

Table 1: Transmitted Status, Warning and Alarm Codes

Signal	Engineering Unit
Fuel Cell Stack Temperature	ºC
Fuel Cell Stack Voltage	Volts
Fuel Cell Stack Current	Amps
Hydrogen Pressure	Barg
Hydrogen Concentration	Ppm
Cumulative Hydrogen Consumption	Slpm
Oxygen Concentration	%
Ambient Temperature	ºC
Purge Cell Voltage	mV

Table 2: Transmitted Transducer Signals

1.8 Safety Systems

The Nexa™ power module provides automatic provisions to ensure operator safety and prevent equipment damage. A warning or alarm occurs when an unusual or unsafe operating condition occurs, depending on severity. During a warning, the power module continues to operate and the controller attempts to remedy the condition if possible. During an alarm, the controller initiates a controlled shutdown sequence. The Nexa™ power module employs the following monitoring and shut down mechanisms to ensure safe fuel cell operation is maintained at all times:

- Fuel cell operating parameters are continuously monitored to ensure they stay within desired limits. These include fuel cell stack operating temperature, fuel cell stack current, output voltage and fuel supply pressure. Warnings and shut down alarms are implemented on each of these parameters

- A Cell Voltage Checker (CVC) system continuously monitors the operation and performance of individual cell pairs. The presence of a failing cell will cause the Nexa™ system to shut down.

- A hydrogen leak detector is implemented within the fuel delivery subassembly. Imbedded properly into the cooling air stream, this sensor can also detect excessive hydrogen purge amounts or the presence of an external fuel leak in the fuel cell stack. The Nexa™ system will shut down automatically if an external hydrogen leak is detected.

- The Nexa™ power module comes equipped with an oxygen sensor for measuring ambient oxygen concentrations. This feature prevents users from operating the Nexa™ system in non-ventilated areas, where oxygen depletion may become a safety concern. The power module shuts down automatically when low ambient oxygen concentration levels are measured.

In addition to warnings and alarms, other safety features are included to the design of the Nexa™ power module:

- A fuel shutoff solenoid valve closes whenever the power module is shut down. This isolates the fuel supply and prevents hydrogen from entering the fuel cell stack in the event of an alarm shutdown.

- Under normal operation, hydrogen released by way of the purge solenoid valve mixes with the cooling air stream, where it quickly diffuses and dilutes to levels far below the LFL of hydrogen. This eliminates the potential formation of a flammable gas mixture in the cooling air flow and permits indoor operation.

- A pressure relief valve discharges hydrogen into the cooling air stream during overpressure conditions to protect the fuel cell stack from damage. When the relief valve opens, the hydrogen concentrations measured in the cooling air stream exceed the hydrogen sensor alarm setting, and the power module shuts down.

2 Specifications

Specifications for the Nexa™ power module are provided in this manual for reference only. The specifications presented in this document do not supersede and in no way replace or substitute for the specifications that are attached to or referenced by a Sales Agreement with Ballard Power Systems. Refer to your Sales Agreement for Product Specifications and Shipping and Storage Specifications for your Nexa™ modules. Contact Ballard Customer Service if you have questions.

2.1 Product Specification

Output specifications for the Nexa™ power module include power, emissions, physical characteristics and lifetime. These specifications are attributes of the Uninstalled Nexa™ power module and do not necessarily reflect the installed performance. Required system inputs are also defined, including fuel delivery, battery input specifications and operating environment requirements. Nexa™ specifications are subject to change. Refer to the Ballard document Nexa™ Product Specification, attached to your Sales Contract, for the specifications of your Nexa™ modules.

The Nexa™ Product Specification is shown in Table 4, with definitions provided in Table 3. Performance and lifetime specifications are given, along with required system inputs for operation. Please note that the Product Specification does not address the following considerations.

- The Warranty period is defined by the Sales Agreement.
- Outdoor applications for the Nexa™ module were not evaluated under UL component recognition.

Beginning of Life	Within the first 20 hours of module operation, within 90 days of receipt from Ballard.
End of Life	Characterised by performance below 22V or a non-repairable fuel cell stack failure.
Cold Start	The temperature of the entire Nexa™ power module is at equilibrium with the ambient air temperature.
Indoors or Outdoors	Any location where the Nexa™ power module is protected by the end product outer enclosure against wet, marine, freezing or other inclement conditions and against sand, dust or other particulates.
Uninstalled	Not installed into an enclosure nor integrated with an external thermal management system, fuel supply system or power conditioning system.
Standard Conditions	Evaluated at sea level at an ambient (cooling air and oxidant air) temperature of 30°C.
Voltage at Rated Power	Measured as the minimum 60 second running average within the first 30 minutes of continuous use. At time of module shipment, Rated Power and Voltage will be within +/- 5% of listed specifications.

Table 3: Nexa™ Product Specification Definitions

OUTPUTS	Requirement	Definition	Quantity
Power	Rated Power	Output power capacity at Standard Conditions, Beginning of Life	1200 W
	Voltage	Operating voltage range	22 V to 50 V
		Voltage at Rated Power	26 V
	Start-up Time	Minimum time to achieve Rated Power from a Cold Start condition	2 minutes
Emissions	Noise	Maximum noise emission at 1m	72 dBA
	Water	Maximum quantity of liquid water produced at Rated Power	790 mL/hr
Physical	Dimensions	L x W x H	56 x 25 x 33cm
	Mass	Total system mass	13 kg
Lifetime	Operating Life	Minimum number of operating hours before End of Life	1500 hours
	Cyclic Life	Minimum number of start-up & shut-down cycles before End of Life	500
	Shelf Life	Minimum storage (non-operation) time before End of Life	2 years; requires >5 min operation every 3 months
INPUTS	**Requirement**	**Definition**	**Quantity**
Fuel	Purity	Lowest acceptable concentration of hydrogen	99.99% H_2 (vol)
	Pressure	Allowable range of inlet supply pressure	70 – 1720 kPa(g)
	Acceptable Impurities	Maximum total inert fluids (including helium, argon, nitrogen and water vapour)	0.01% (vol)
		Maximum CO and CO_2 combined	2 ppm (vol)
		Maximum total hydrocarbon	1 ppm (vol)
		Maximum oxygen	500 ppm (vol)
	Consumption	Maximum fuel consumption at Rated Power	<18.5 SLPM
Power Conditioning	Current Ripple	Maximum acceptable current ripple at 120 Hz, with respect to average DC net output current	24.7% RMS 35% peak-peak
DC Power Supply	Voltage	Allowable range of input voltage	18 V to 30 V
	Power	Maximum power draw during start-up	60 W
Operating Environment	Location	Acceptable locations for use	Indoors and Outdoors
	Temperature Range	Range of acceptable ambient, cooling air and oxidant air temperatures	3°C - 40°C
	Relative Humidity	Range of acceptable ambient relative humidity	0% - 95% (non-condensing)
	Electromagnetic Interference Tolerance	Tolerant to and operates safely in the EMI environment specified by	UL 991

Table 4: Nexa™ Product Specification

2.2 Shipping & Storage Specification

This document addresses required methods and criteria for packaging, shipping and storing the Nexa™ power module, as well as end products developed using the Nexa™ module. Adhere to these specifications to ensure that damage or performance loss does not occur.

The identified Original Packaging Assembly is to be used for all shipments of the Nexa™ power module. Warranty returns of Nexa™ modules to Ballard must be packaged in the designated shipping crate assembles. Nexa™ packaging must be in good condition. Physical damage to the crate, due to misuse or outside storage, will void the warranty claim.

Nexa™ specifications are subject to change. Refer to the Ballard document Nexa™ Shipping and Storage Specification, attached to your Sales Contract, for the specifications of your Nexa™ modules.

	Requirements	Definition / Description	Quantity
Nexa™ Module Packaging[1]	Crate Assembly, Nexa™ Single Pack	Nexa™ Single Pack	Part # 5000233 DRW5000224
	Packaging Foam, Lower Pad		Part # 5000234 DRW50000225
	Packaging Foam, Top Pad		Part # 5000226 DRW5000235
End Product Packaging	Packaging Foam	The following packaging foam is recommended for packaging end products using the Nexa™ module: Stratocell® Polyethylene Foam, a product of Sealed Air Corporation, Park 80 East, Saddle Brook, NJ, 07663. Consult Ballard before using other foams, styrofoams or materials.	
Transport	Mode(s) of Transport	The Nexa™ power module is capable of being shipped by either rail, water, road or air.	
	Mode of Operation During Transport	The Nexa™ power module will not be operated when being transported.	
	Ambient Temperature	Allowable range of ambient temperature.	-29 C to 70 C
	Shock Loads During Transport	The Nexa™ module and original packaging has been developed and tested according to the requirements of ISTA packaging standards, test procedure 1. The OEM packaging must also be developed and tested in accordance with ISTA test procedure 1 (or an equivalent industry packaging standard.)	
	Drop and Topple	The Nexa™ power module can withstand drop and topple abusive loads, as described in the test methods of IEC publication 68-2-31, Drop and Topple Basic Environmental Testing Procedures.	
	Drop Test	The Nexa™ power module can withstand a free fall from a height of 1.2m onto a hard surface (concrete or steel). Any failures directly or indirectly emanating from such a load condition shall not present a safety hazard.	
Storage	Ambient Temperature	Allowable range of ambient temperatures.	-29°C to 70°C
	Freezing Storage	Allowable number of freeze/thaw cycles.	50 Cycles
	Relative Humidity	Range of allowable ambient relative humidity	5% to 95%

NOTES: 1. The identified Original Packaging Assembly is to be used for all shipments of the Nexa™ power module. Warranty returns of Nexa™ power modules to Ballard must be packaged in the designated shipping crate assembles. Nexa™ packaging must be in good condition. Physical damage to the crate, due to misuse or outside storage, will void the warranty claim.

Table 5: Nexa™ Shipping and Storage Specification

2.3 Interface Specifications

Interface specifications are provided for the Nexa™ power module, to enable gas, electrical and communication connections for lab installation. The Nexa™ module interfaces are illustrated in Figure 4. Specifications for interface connections follow the figure. Italicised component labels are for reference only.

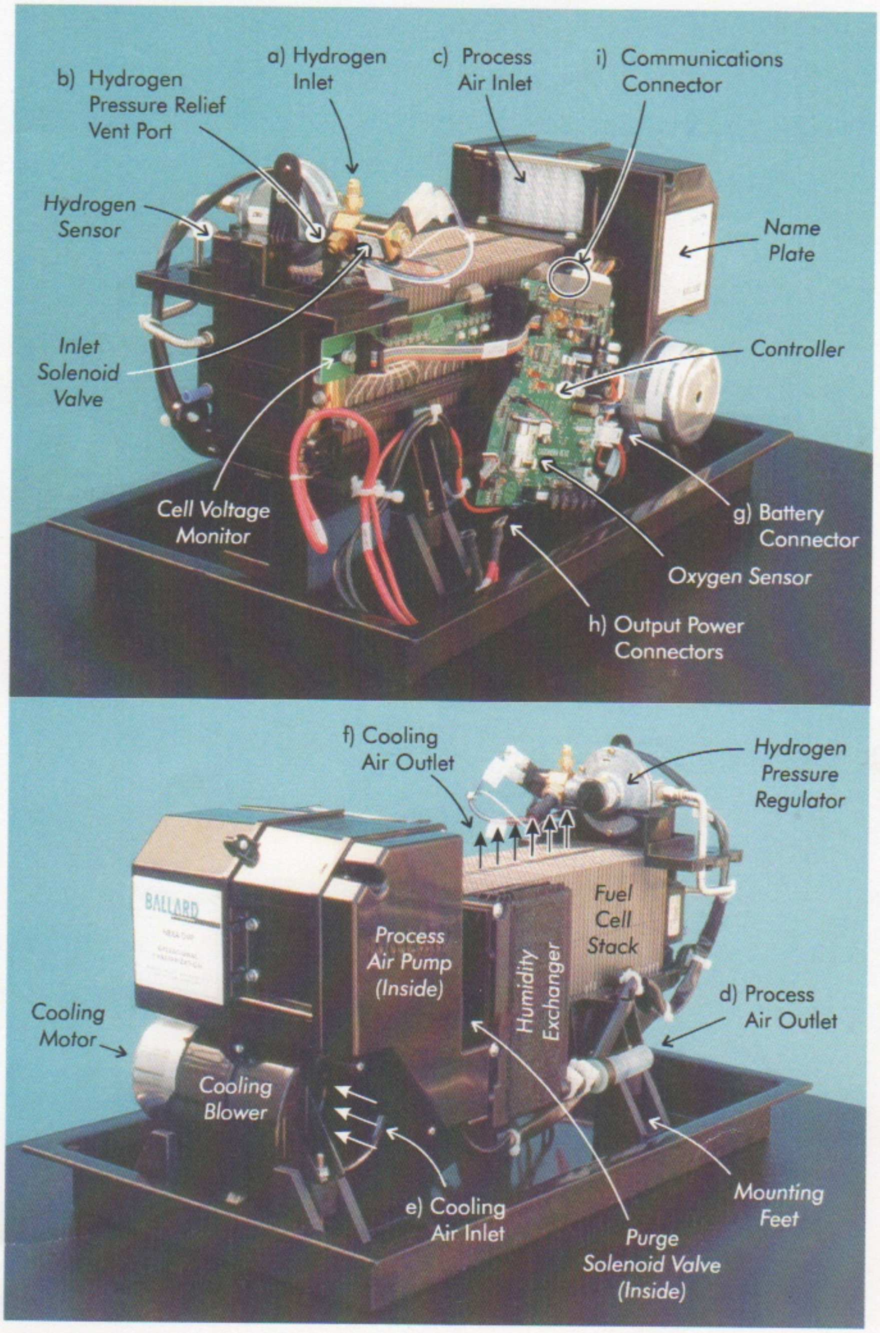

Figure 4: Nexa™ Component Layout and Interfaces

2.3.1 Hydrogen Inlet

The hydrogen inlet draws hydrogen from the fuel storage containers for use in the fuel cell power reaction. Specifications for the hydrogen inlet connection are provided in Table 6. The Nexa™ fuel cell system is designed for operation on *pure* gaseous hydrogen. No fuel humidification is required. Hydrogen can be supplied at pressures ranging from 70 to 1720 kPa(g) (10 to 250 psig). A pressure relief valve is located on the fuel assembly immediately upstream of the fuel regulator. The relief valve vents at 2400 kPa(g) (350 psig) to ensure overpressure conditions are not applied to the downstream pressure regulator assembly. The relief valve discharges into the vicinity of the onboard hydrogen leak detector, thereby shutting down the system in the event of excessive inlet supply pressure. Table 6 also indicates the required hydrogen purity and allowable contaminant levels for the fuel supply. Adhere to the fuel composition specification to ensure proper Nexa™ system performance.

Description	Specification
Composition	99.99% hydrogen < 0.01% Maximum total inert fluids (He, N_2, Ar, and water vapour) < 2 ppm carbon dioxide + carbon monoxide < 500 ppm oxygen < 1 ppm sulfur compounds < 1 ppm hydrocarbons
Pressure	70 to 1720 kPa(g)
Temperature	5 to 80 °C
Flow	≤ 18.5 slpm at maximum power
Pressure Relief Valve Setting	2400 kPa(g)
Connection	45° flared tube fitting (male) for 1/4" OD tubing

Table 6: Hydrogen Inlet Connection

2.3.2 Process Air Inlet

The process air inlet draws air from the ambient surroundings for use in the fuel cell power reaction. Specifications for the process air inlet connection are provided in Table 7.

Description	Specification
Composition	Ambient air
Pressure	Atmospheric
Flow	≤ 90 slpm
Connection	None – External ducting is recommended to separate the process air inlet stream from the cooling air outlet.

Table 7: Process Air Inlet Connection

2.3.3 Process Air Outlet

The process air outlet expels oxygen-depleted air after its use in the fuel cell power reaction. Excess product water from the fuel cell power reaction is entrained in the process outlet air stream in both liquid and vapour form. Specifications for the process air outlet connection are provided in Table 8.

Description	Specification
Composition	Oxygen-depleted air
Maximum allowable flow restriction on outlet connection, measured as pressure drop to ambient	3.44 kPa (0.5 psi) at 100 SLPM, 55°C
Temperature	< 55 °C; depends on the fuel cell stack operating temperature
Flow	See process air inlet
Entrained Product Water	870 mL/hour maximum at rated power
Connection	16 mm OD tube

Table 8: Process Air Outlet Connection

2.3.4 Cooling Air Inlet

The cooling air inlet draws air from the ambient surroundings in order to cool the fuel cell stack and regulate operating temperature. Specifications for the cooling air inlet connection are provided in Table 9.

Description	Specification
Composition	Ambient air
Pressure	Atmospheric
Flow	3600 slpm maximum
Connection	None

Table 9: Cooling Air Inlet Connection

2.3.5 Cooling Air Outlet

The cooling air outlet expels warmed air to the ambient surroundings after absorbing heat from the fuel cells. Hydrogen and water, purged from the fuel stream, is released into the cooling air stream. Hydrogen released from the pressure relief vent port during an over-pressure condition also mixes with the cooling air outlet stream. Cooling air outlet specifications are detailed in Table 10.

Description	Specification
Composition	See cooling air inlet
Maximum Allowable Pressure Drop or Back-pressure	0.35 kPa (1.4 inches of water)
Temperature	≅ 17ºC above inlet stream
Flow	See cooling air inlet
Connection	None - External ducting is recommended to separate the cooling air outlet stream from the process air inlet.

Table 10: Cooling Air Outlet Connection

2.3.6 Output Power Connections

The output power connections deliver the unregulated DC output power generated by the fuel cell stack. Specifications for the output power connection are provided in Table 11.

Description	Specification
Power (net)	0 W minimum at idle 1200 W maximum continuous at BOL
Voltage (unregulated)	22-50 VDC at beginning of life, standard operating conditions (sea level, 30°C)
Maximum Imposed Current Ripple	24.7% rms at 120 Hz maximum throughout the operating range; equivalent to 35% peak-to-peak
Connection	AMP 2-321598-3 ring terminal (1/4" ID) for use with STUD: ¼"–20 UNC
Pin-out	P1-2: Power – (Black) P1-1: Power + (Red)

Table 11: Output Power Connection

2.3.7 Battery Connector

The battery connector draws external battery power to start and shut down the Nexa™ power module. During start-up, the battery remains connected for providing parasitic loads until the Nexa™ module completes its start-up process and is running normally. Once running, the fuel cell system provides its own parasitic power. The battery remains disconnected from the Nexa™ control board until the stack voltage falls below 18V or the Nexa™ module is shut down. During shut down, the battery is reconnected for providing parasitic power. Specifications for the battery input connection are provided in Table 12.

Description	Specification
Voltage	18 to 30 VDC
Energy Draw	60 W for 60 seconds maximum
Connector	2-way AMP 643226-1 female header Mates with AMP 350777-1 plug and AMP 350922-3 male terminals
Pin-out	J2-1: Battery – J2-2: Battery +

Table 12: Battery Input Connection

2.3.8 Communications Connector

The communications connector provides input, output and communication signals between the Nexa™ power module controller and host equipment. Communications connection specifications are provided in Table 13.

Description	Specification
Communications	
Standard	RS-485 serial
Baud	9600
Start Bits	1
Data Bits	8
Parity	none
Stop Bits	1
Configuration	Full duplex (asynchronous data transmission)
Data Protocol	Serial Line Internet Protocol (SLIP); Internet RFC 1055
Transmit	
Message Period	200 ms, continuous
Message Length	43 bytes to 143 bytes
Receive	
Message Length	5 bytes
Solenoid Valve Output Signal	
Logic	High (13.5 VDC) = open; Low (0 VDC) = closed
Type	Open drain to ground
Voltage	13.5 VDC
Current	0.5 A
Load Contactor Output Signal	
Logic	High (13.5 VDC) = on/closed circuit; Low (0 VDC) = off/open circuit
Type	Open drain to ground
Voltage	13.5 VDC
Current	0.2 A

On/Off Input Signal	
Logic	Current flow = on; No current flow = off
Type	Optically coupled
Voltage Drop Across Input	1.4 VDC maximum
Current	3 – 5 mA; 10 mA maximum
Input Impedance	1 kΩ
Connector	42-way AMP 638184-6 male header Mates with 16-way AMP 174514-1 plug and 040 AMP 345160-1 female receptacles
Pinout	J4-B1: Reserved J4-B2: Reserved J4-B3: External output; tank solenoid valve – J4-B4: External output; tank solenoid valve + J4-B5: External input; on/off signal – J4-B6: External input; on/off signal + J4-B7: External output; load contactor – J4-B8: External output; load contactor + J4-B9: Reserved J4-B10: Reserved J4-B11: Ground J4-B12: Communications common J4-B13: Communications receive – J4-B14: Communications receive + J4-B15: Communications transmit – J4-B16: Communications transmit +

Table 13: Communications Connector

3 Safety

NOTE

The safety guidelines included here may not cover every situation. Use common sense.

3.1 General Information

For this unit to generate electrical power, a supply of hydrogen fuel is necessary. It is important for any operator to be aware of, understand, and follow all local safety requirements related to the handling of hydrogen and compressed gases. Ensure that your facility conforms to all local regulatory requirements, including building codes and recommendations.

The fuel cell system has built-in safeguards and is designed to shut down automatically if any out-of-range operating condition occurs. Possible situations include low cell voltage, high current, high temperature, low fuel pressure, or hydrogen leak detection.

- Do not operate the Nexa™ power module on a grade of more than 45 degrees.
- Do not connect or disconnect power cables when the fuel cell module is energised.
- Do not dismantle the Nexa™ system. Contact Ballard if you have any concerns about operation.

3.2 Using Hydrogen

WARNING! FIRE OR EXPLOSION

Keep all sources of ignition away from hydrogen.

This unit uses hydrogen fuel. Hydrogen is a colourless, odourless and flammable substance. It is highly combustible in the presence of oxygen and burns with a colourless flame.

Leaking gas may be hot and pose a burn danger. Stop the flow of gas – if you are not in danger – and use water to cool the area. If fire occurs, do not attempt to extinguish flames, allow the fire to burn out.

Prevent overexposure to hydrogen. Hydrogen is non-toxic but can act as a simple asphyxiant by displacing the oxygen in the air. There are no warnings before unconsciousness results. When operating the Nexa™ power module in an enclosure:

- Ensure ventilation slots are clear and unobstructed at all times during operation
- Operate within the temperatures limits stated on the Nexa™ system nameplate
- Never operate if an alarm condition exists

3.2.1 Handling Compressed Gas Cylinders

WARNING!

Do not handle compressed hydrogen gas cylinders without training or experience.

- Use a pressure regulator to control the fuel inlet pressure to the Nexa™ system.
- Do not alter the fitting on a regulator. Ask experienced personnel for help.
- Do not attempt to force gas cylinder threads.
- Never transport a gas cylinder with regulators attached. Ensure cylinder caps are in place. Always use a cylinder cart with a safety strap or chain.
- Secure a high-pressure cylinder to a bench, post, or fixed object to avoid accidental contact.
- Avoid unnecessary contact with On/Off valves. They can easily move to "On" by accident.

3.2.2 Hydrogen Leakage

Hydrogen is colourless, odourless and tasteless. Hydrogen is non-toxic but can act as a simple asphyxiant by displacing the oxygen in the air. There are no warning symptoms before unconsciousness results.

WARNING!

Inhaling hydrogen can lead to unconsciousness and asphyxiation.

Hydrogen molecules are smaller than any other gas, making hydrogen more difficult to contain. It can diffuse through many materials considered airtight. Fuel lines, non-welded connections, and non-metal seals such as gaskets, O-rings, pipe thread compounds and packings present potential leakage or permeation sites. Furthermore, hydrogen's small molecule size results in high buoyancy and diffusivity, so leaked hydrogen will rise and become diluted quickly.

Constant exposure to hydrogen causes hydrogen embrittlement in many materials. The mechanisms that cause hydrogen embrittlement effects are not well defined. Factors known to influence the rate and severity of hydrogen embrittlement include hydrogen concentration, hydrogen pressure, temperature, hydrogen purity, type of impurity, stress level, stress rate, metal composition, metal tensile strength, grain size, microstructure and heat treatment history. Moisture content in the hydrogen gas may lead to metal embrittlement through the acceleration of the formation of fatigue cracks. Hydrogen embrittlement can lead to leakage or catastrophic failures in metal and non-metallic components.

Hydrogen leaks emanating from the fuel cell stack are readily detected by way of the hydrogen sensor mounted in the cooling air outlet stream. This sensor triggers warnings and alarms well before the hydrogen/air mixture reaches a flammable concentration.

As a preventative measure, the Nexa™ power module must be operated in a well-ventilated area in order to inhibit potential hydrogen accumulation.

WARNING!

Always operate the Nexa™ power module in a well-ventilated area and ensure that ventilation slots are unobstructed.

3.2.3 Flammability and Volatility

Hydrogen is flammable over concentrations of 4 – 75% by volume in air, and is explosive over concentrations of 15 – 59%. As a result, even small leaks of hydrogen have the potential to burn or explode. Leaked hydrogen can concentrate in an enclosed environment, thereby increasing the risk of combustion and explosion.

Hydrogen flames are pale blue and are almost invisible in daylight due to the absence of soot. Due to its high buoyancy and diffusivity, burning hydrogen rises unlike gasoline, which spreads laterally.

A flammable or explosive hydrogen mixture is easily ignited by a spark or even a hot surface. The auto-ignition temperature of hydrogen is 500 °C (932 °F). The energy of a hydrogen gas explosion is 2.4 times that of gasoline or methane for an equal volume. Hydrogen gas explosions are therefore more destructive and carry further.

WARNING!

A mixture of hydrogen and air is potentially flammable and explosive and can be ignited by a spark or a hot surface.

As in the presence of any fuel, all sources of ignition, including smoking, are not permitted in the vicinity of the power module.

WARNING!

Keep all sources of ignition away. Smoking is not permitted in the vicinity of the Nexa™ power module.

3.3 Oxygen Depletion

Oxygen is a colourless, odourless, non-toxic and tasteless gas. Oxygen is essential for life in appropriate concentrations.

Ambient air contains up to 21% oxygen. Oxygen levels below 19.5% are biologically inactive and may act as simple asphyxiants. Effects of oxygen deficiency may include: rapid breathing, diminished mental alertness, impaired muscular coordination, faulty judgement, depression of all sensations, emotional instability, and fatigue. As asphyxiation progresses, nausea, vomiting, prostration, and loss of consciousness may result, eventually leading to convulsions, coma, and death. At concentrations below 12%, immediate unconsciousness may occur with no prior warning symptoms.

WARNING!

Lack of oxygen can lead to unconsciousness and asphyxiation.

Oxygen is consumed from the ambient air during power module operation. To guard against oxygen depletion, an oxygen sensor mounted on the controller monitors the ambient oxygen concentration. This sensor triggers warnings and alarms before the oxygen concentration drops to a dangerous level.

As a preventative measure, the Nexa™ power module must be operated in a well-ventilated area in order to compensate for the oxygen used within the fuel cells.

WARNING!

Always operate the Nexa™ power module in a well-ventilated area.

3.4 Electrical Safety

WARNING!

Avoid contact with an exposed fuel cell stack. Electrical shock can cause personal injury or death.

- Do not touch fuel cell plates or any electrical components at any time. A running fuel cell stack is a potential electrical hazard that can cause burns or electrical shock.
- Do not wear metallic jewelry – rings, bracelets, watchbands, or necklaces – when you are close to an exposed fuel cell stack.
- Minimise static discharge. If possible, ground all equipment.

- Minimise conductivity. Avoid contact with surfaces that are in contact with water or gases. Do not operate or store in wet or damp conditions
- Use a three-wire grounding plug when connecting electrical devices
- Never use damaged extension cords

The Nexa™ power module generates up to 50 VDC (open circuit voltage). This voltage decreases as current is drawn from the module. The Nexa™ power module produces 26V at maximum power. This voltage is exposed at the output power connections. These low voltages may constitute a shock hazard and can damage electronic components if shorted. Therefore, do not touch individual fuel cells, cell voltage monitoring equipment or electrical components.

WARNING!

Do not touch fuel cells, cell voltage monitoring equipment or electrical components.

Electronic components can also be damaged as the result of static discharge. To minimise this, ground all equipment in contact with the power module. Use a three-wire grounding plug when connecting external loads. Never use damaged extension cords. Minimise conductivity by avoiding surfaces in contact with water; hands and clothes must be dry. Do not operate or store the power module in wet or damp conditions.

WARNING!

Minimise static discharge. Ground all equipment.

Residual reactants within the Nexa™ power module can develop a charge in a matter of minutes when turned off. A reading of zero volts across the entire power module does not guarantee that all fuel cells are uncharged.

WARNING!

Always assume that the fuel cell stack is charged.

Jewelry (such as rings, necklaces, bracelets and watches) may concentrate an electric current when it comes into contact with charged components, or when a shock passes through the human body. Accordingly, no jewelry should be worn near the power module.

WARNING!

Do not wear jewelry near the Nexa™ power module.

3.5 High Temperature

The fuel cell stack is designed to operate at 65°C. At this operating temperature, the air exhaust stream temperature can reach 55°C and the cooling air stream can reach 17°C above ambient conditions. These temperatures are sufficient to cause burns or severe discomfort. Accordingly, avoid contact with the fuel cell stack, or components that convey process or cooling air.

WARNING!

Avoid contact with the fuel cell stack or components that convey process or cooling air.

3.6 High Pressure

Process air and hydrogen gas streams within the Nexa^{TM} power module are regulated to low pressure. These circuits do not pose a high-pressure hazard, and they automatically vent and/or depressurise when the module is shut down.

Hydrogen pressure feeding the power module may reach 17 barg and will typically remain pressurised even when the module is shut down. This high pressure is potentially dangerous. Use caution and ensure that the circuit is de-pressurised prior to access.

WARNING!

Ensure gas circuits are depressurised prior to access. Do not loosen fittings while under pressure. Doing so may result in uncontrolled gas release.

3.7 Rotating Equipment

The Nexa^{TM} power module contains a process air pump and a cooling air fan that contains rotating parts. During normal operation, the air pump is enclosed within the module ductwork whereas the fan is partially exposed. Take care to avoid contact with rotating equipment, especially if protective enclosures have been removed to facilitate maintenance. Loose clothing may become entrained in rotating equipment and should not be worn.

WARNING!

Do not wear loose clothing while operating the NexaTM power module. Do not remove protective enclosures.

4 Installation

Figure 5 illustrates the basic installation of a Nexa™ power module in the lab and the mechanical, electrical and software interfaces necessary for operation. Before getting started, ensure that the following test lab criteria and installation procedures are satisfied:

- Ensure that the Nexa™ system is installed in a well-ventilated lab area equipped with hydrogen alarm sensors. Alternatively, install the Nexa™ unit underneath a fume-hood.
- Ensure the air quality of the test lab is sufficient for fuel cell operation. For example, do not operate the Nexa™ system adjacent to gasoline generators or in a non-ventilated room.

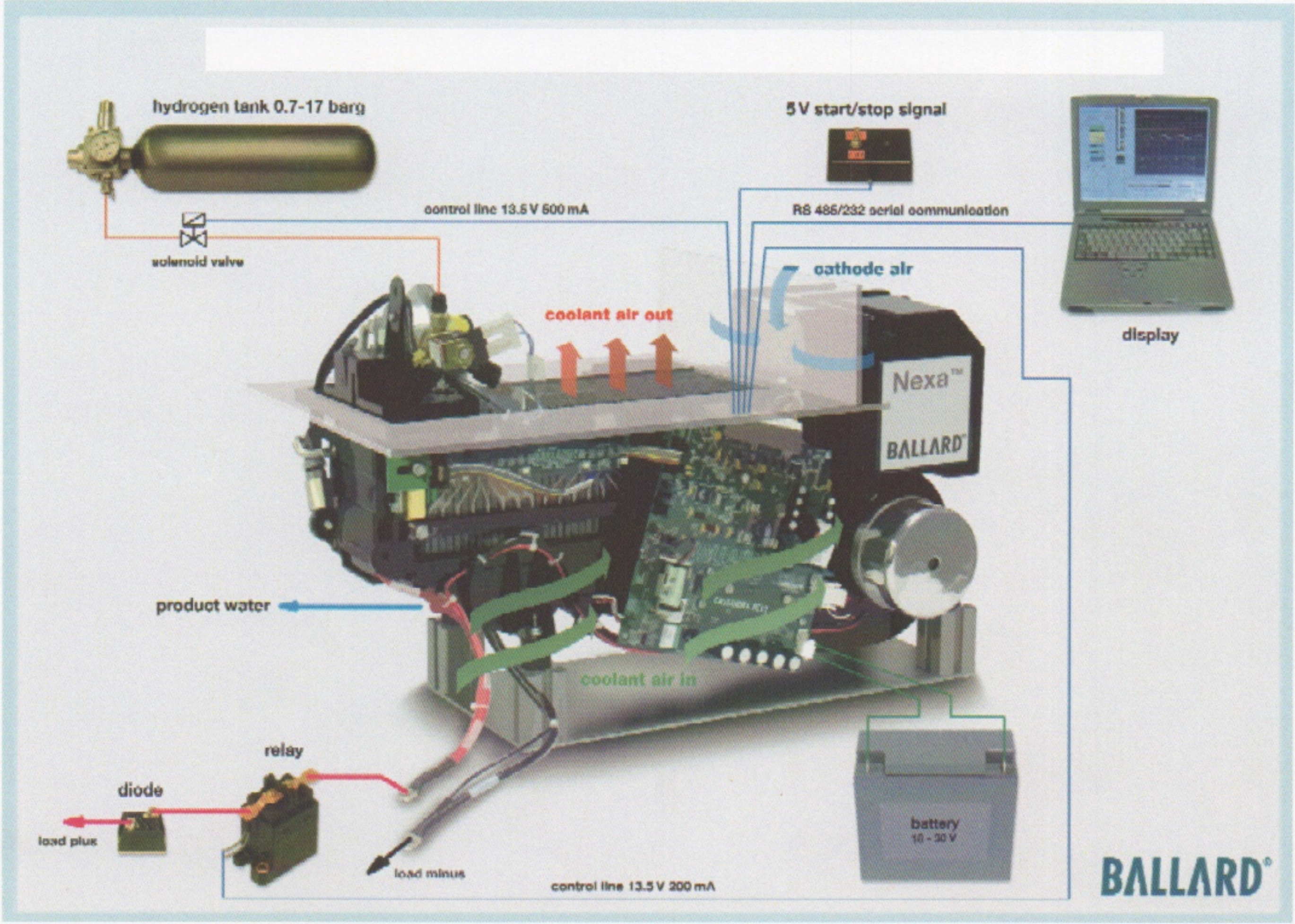

Figure 5: Installation of the Nexa™ power module

Follow the provided instructions to establish a laboratory test station for the Nexa™ power module.

- Install the Nexa™ power module onto a stand using the mounting feet, as shown in Figure 5.
- Provide a suitable supply of hydrogen. Connect the fuel supply to the hydrogen connection, as shown in Figure 5. Refer to the Interface Specifications for detailed fuel purity and connector specifications.
- Connect a 24 VDC battery to the Nexa™ control board, as shown in Figure 5. Alternatively, you may use a 24 VDC power-supply. Ensure the power supply is capable of at least 6 amps to support current surges on system start-up. Refer to the Interface Specifications for detailed installation and connector specifications.
- Install a load relay on the positive output terminal of the fuel cell stack to prevent premature power draw from the Nexa™ module. Connect the load relay control signal to the Nexa™ serial communication port, as shown in Figure 5. Make sure to test the load relay is working properly before operating the system. Refer to the Interface Specifications for connection details.
- Connect a blocking diode on the positive output terminal of the fuel cell stack, as shown in Figure 5, to prevent applying reverse potential to the fuel cell stack by a battery or some other DC power module integration.
- Connect the positive and negative output terminals of the Nexa™ module to a DC load bank for providing a load during system testing.
- Provide a 5 V start signal to the Nexa™ serial communication port, as shown in Figure 5. Refer to the Interface Specifications for connection details.
- Provide suitable water drainage for the oxidant air exhaust line.
- Connect the Nexa™ serial communication port to a computer through a RS485 to RS232 converter. Refer to the Interface Specifications for the serial interface connection details.
- Develop interface software to read and log Nexa™ operational data transmitted through the serial message. Refer to the Software Interface of the Integration Guide for the messaging format and communication protocol specifications.

For new customers who may be unfamiliar with Nexa™ power module installation, an Installation Kit can be provided as part of the purchase. The kit provides interface hardware to enable quick and easy installation in the test lab. Labview software is also provided as part of the installation Kit, which provides basic monitoring and logging and features.

4.1 Installation Kit

The Installation Kit is illustrated in Figure 6. It contains the following equipment to enable quick and easy installation of the Nexa™ module into a test lab:

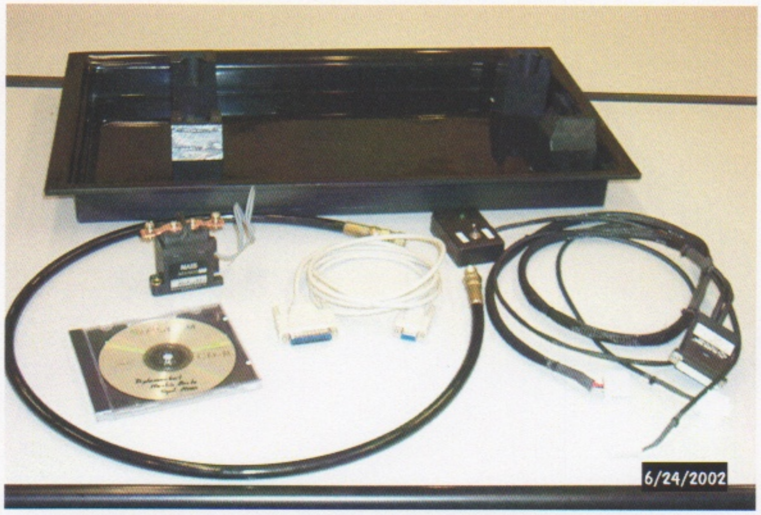
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Figure 6: Nexa™ Installation Kit

- Communications Wiring Harness – The communications wiring harness provides several functions. It is used to connect the Nexa™ control board to a 24 V power supply for providing standby and start-up power to sensors and other onboard components. It is also used to send serial information from the Nexa™ module to a laboratory computer for monitoring and diagnostic purposes. The cable connects to the RS485 communications port of the Nexa™ control board and provides an RS485 to RS232 converter for interfacing with a computer's serial port. In addition, the harness includes a start switch, which applies a 5 V start signal to the control board to start the module. Finally, the harness includes a load relay control cable, which connects the control board to an external load relay for engaging and disengaging loads from the Nexa™ module.
- 25 Pin (male) to 9 Pin (female) Serial Cable – The serial cable is used to connect the RS485 to RS232 converter to the serial port of a laboratory computer.
- Load Relay – The load relay is connected to the positive output terminal of the Nexa™ module to prevent premature power draw. The Nexa™ control board, using the Communications Wiring Harness, controls the load relay.
- Nexa System Tray – The system tray provides mounting posts for the module.
- Hose – A hose is provided to supply hydrogen to the Nexa™ module from a cylinder. One end of the hose incorporates a 45° flared tube fitting, which mates with the hydrogen connection of the Nexa™ unit (see Interface Specifications). The other end uses a ¼" male NPT connection. Always use teflon tape when connecting adapters to NPT fittings.
- Nexamon OEM Software on CD-ROM – Labview software has been developed for providing basic monitoring and diagnostic functions. An installation CD is provided.

Figure 7 illustrates the installation of a Nexa™ module in a laboratory setting. In addition to the Installation Kit, the following additional item are required to operate the Nexa™ module:

- Hydrogen Bottle - Refer to Interface Specifications for hydrogen purity and consumption requirements.
- Pressure Regulator – A pressure regulator must be installed on the hydrogen storage bottle, to reduce the fuel delivery pressure to the Nexa™ module. Refer to the Interface Specifications for the range of allowable hydrogen delivery pressures.
- 24V Power Supply (or battery) - Refer to Interface Specifications for power requirements during system start-up.
- DC load bank – Maximum continuous power demand of 1200W.
- 16mm OD Tube (approximately 6') – The process air exhaust tube interfaces to the base of the humidity exchanger for collecting product water from the fuel cell reaction.
- Bucket for Collection of Product Water – The Nexa™ module produces roughly 790ml/hour of product water at full power.
- Laptop Computer – Refer to the computer hardware requirements for the Ballard monitoring and diagnostic software, presented in the following section.

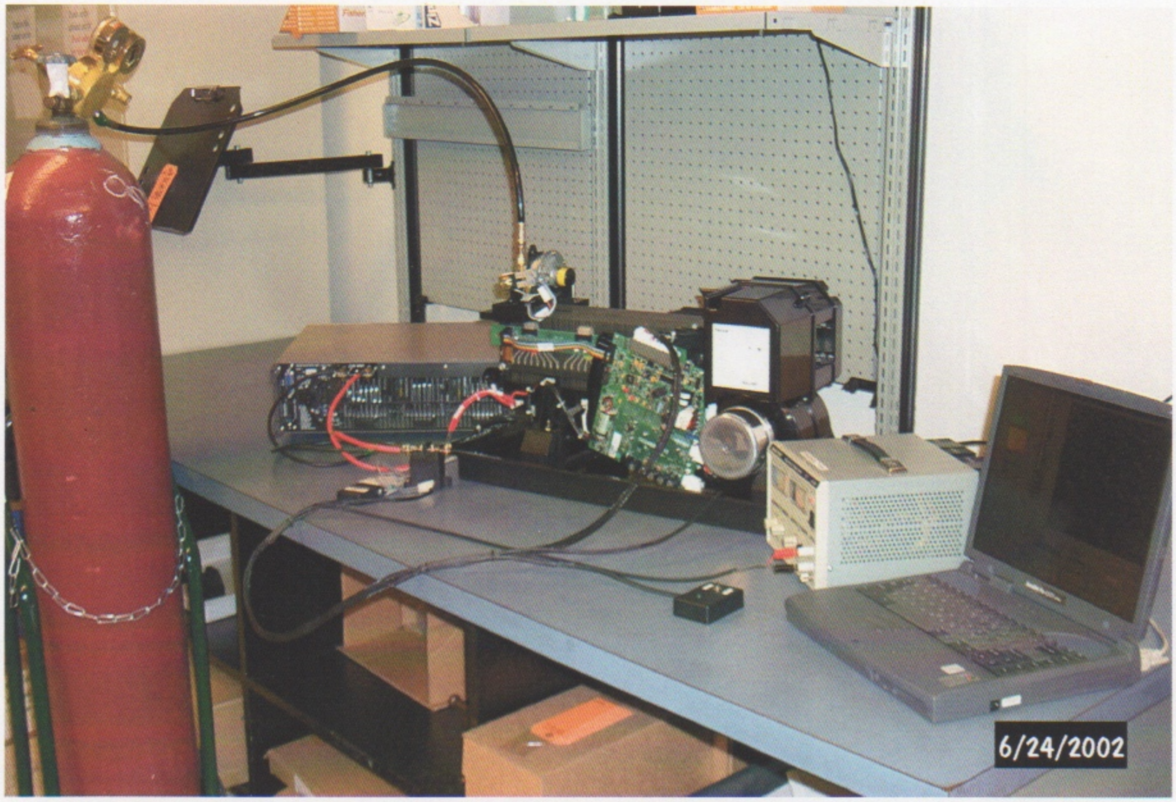
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Figure 7: Nexa™ Laboratory Test Set-up

4.1.1 Installing the NexaTM System Tray

Figure 8 illustrates how the NexaTM module is installed in the system tray. Ensure that the NexaTM system's feet are properly installed in the tray's mounting pads to prevent damage to the control board.

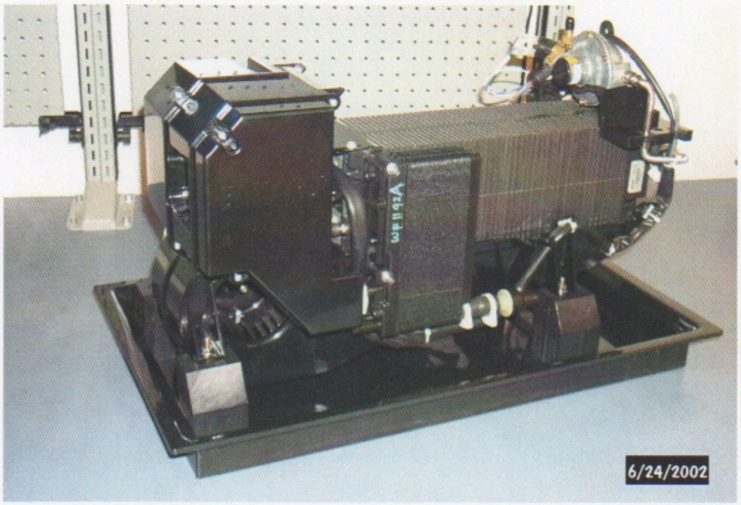

Figure 8: Installing the NexaTM System Tray

4.1.2 Connecting the 24V Power Supply

Figure 9 illustrates the power supply connection to the NexaTM control board, using the Communications Wiring Harness.

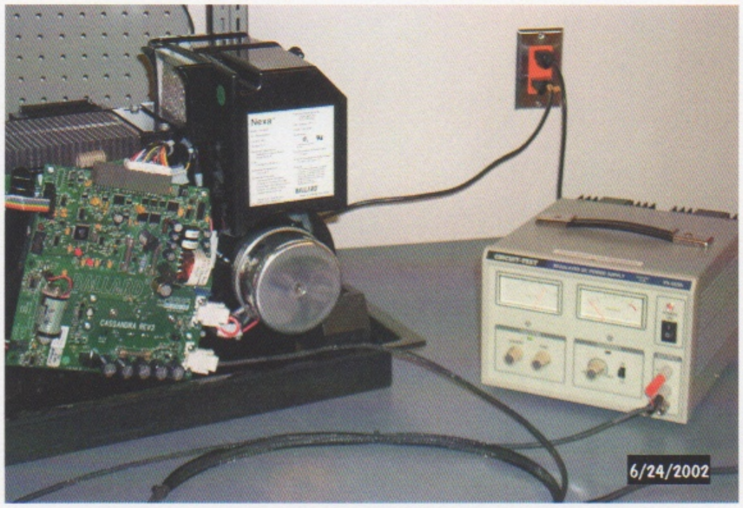

Figure 9: Connecting the 24V Power Supply

4.1.3 Connecting the Communications Port

The Nexa™ communications port provides the interface for all external equipment. Serial messages are transmitted using RS485 protocol to provide fuel cell performance parameters, system states, warnings and alarms to a computer or external controller. A 5 V start signal is applied to the Nexa™ module through the communications port. Control signals are also transmitted here for the actuation of a load relay and external fuel isolation valves. Figure 10 illustrates how the Communications Wiring Harness is connected to the control board.

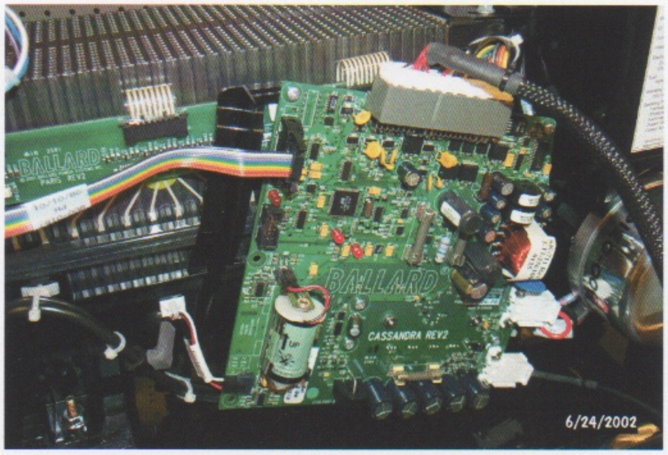

Figure 10: Connecting the Communications Port

4.1.4 Connecting the Serial Cable and Computer

Figure 11 illustrates how the serial cable is used to connect the computer's serial port to the RS485/232 converter box of the Communications Wiring Harness.

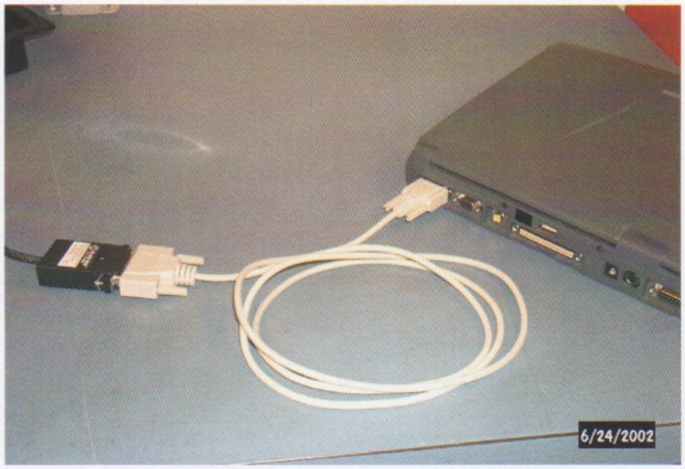

Figure 11: Connecting the Serial Cable and Computer

4.1.5 Installing the Load Relay

Figure 12 illustrates how the load relay is connected to the positive output power lead of the Nexa™ module. The signal wire, which controls the relay, is connected to the Communications Wiring Harness, as shown in the figure. Ensure that the load relay is functioning properly before applying load to the module. Confirm that the relay is open when the Nexa™ module is Off or in Standby, and that it closes only when the unit is Running.

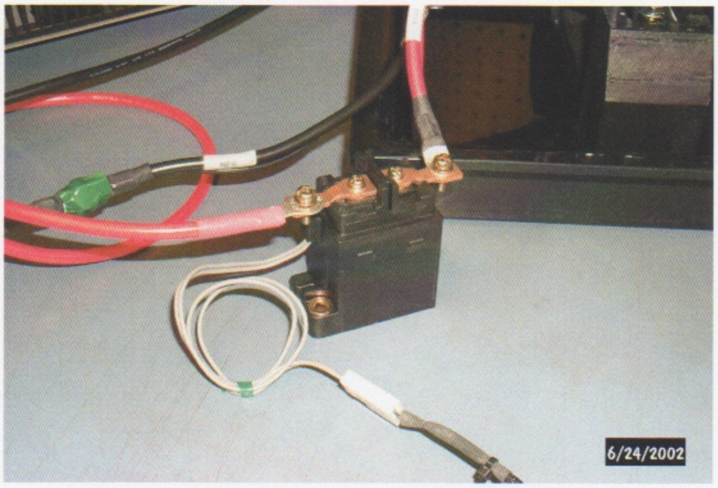
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Figure 12: Installing the Load Relay

4.1.6 Connecting the Hydrogen Supply

Figure 13 illustrates the hydrogen supply connection to the Nexa™ module.

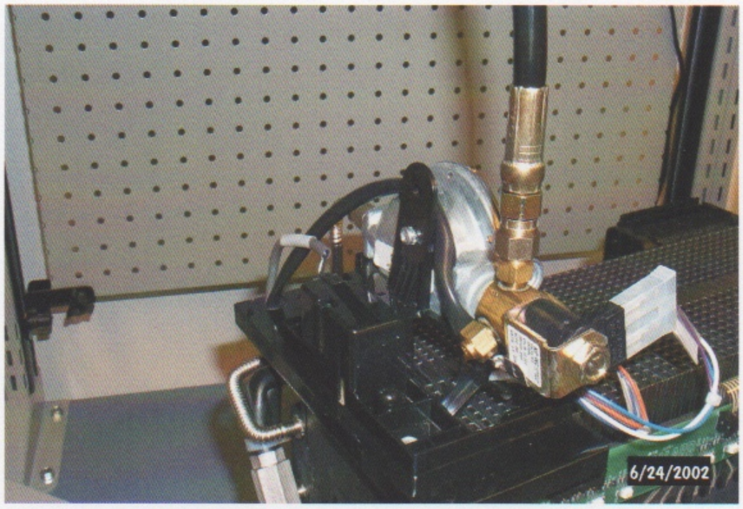
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Figure 13: Connecting the Hydrogen Supply

4.2 NexaMon OEM Software

The Installation Kit comes equipped with a LABVIEW software program, which provides a graphical user interface to the Nexa™ module's operational status and performance. The software program is not needed to operate the Nexa™ module. However, it provides basic data monitoring, logging and diagnostic features that can be very helpful when conducting a fuel cell testing program in the lab. The features and capabilities are described in this manual.

4.2.1 Hardware Requirements

The following computer and hardware requirements must be followed to run the NexaMon OEM software program.

- Pentium computer with Windows 95 or later, a minimum of 166 MHz clock speed, 64 Mb of RAM and a screen resolution of 1024 x 768 pixels. The computer must come equipped with at least one serial port (9-pin male) for serial communications.
- Communications Wiring Harness, complete with an RS232 to RS485 serial protocol converter, as provided in the Installation Kit.
- Serial cable (9-pin female to 25-pin male), as provided in the Installation Kit.

4.2.2 Program Installation

To install the NexaMon OEM program, insert the provided CD, run the setup.exe file and respond to the self-install queries. The software will be automatically installed onto the hard-drive of your computer in the directory C:\Program Files\NexaMon OEM

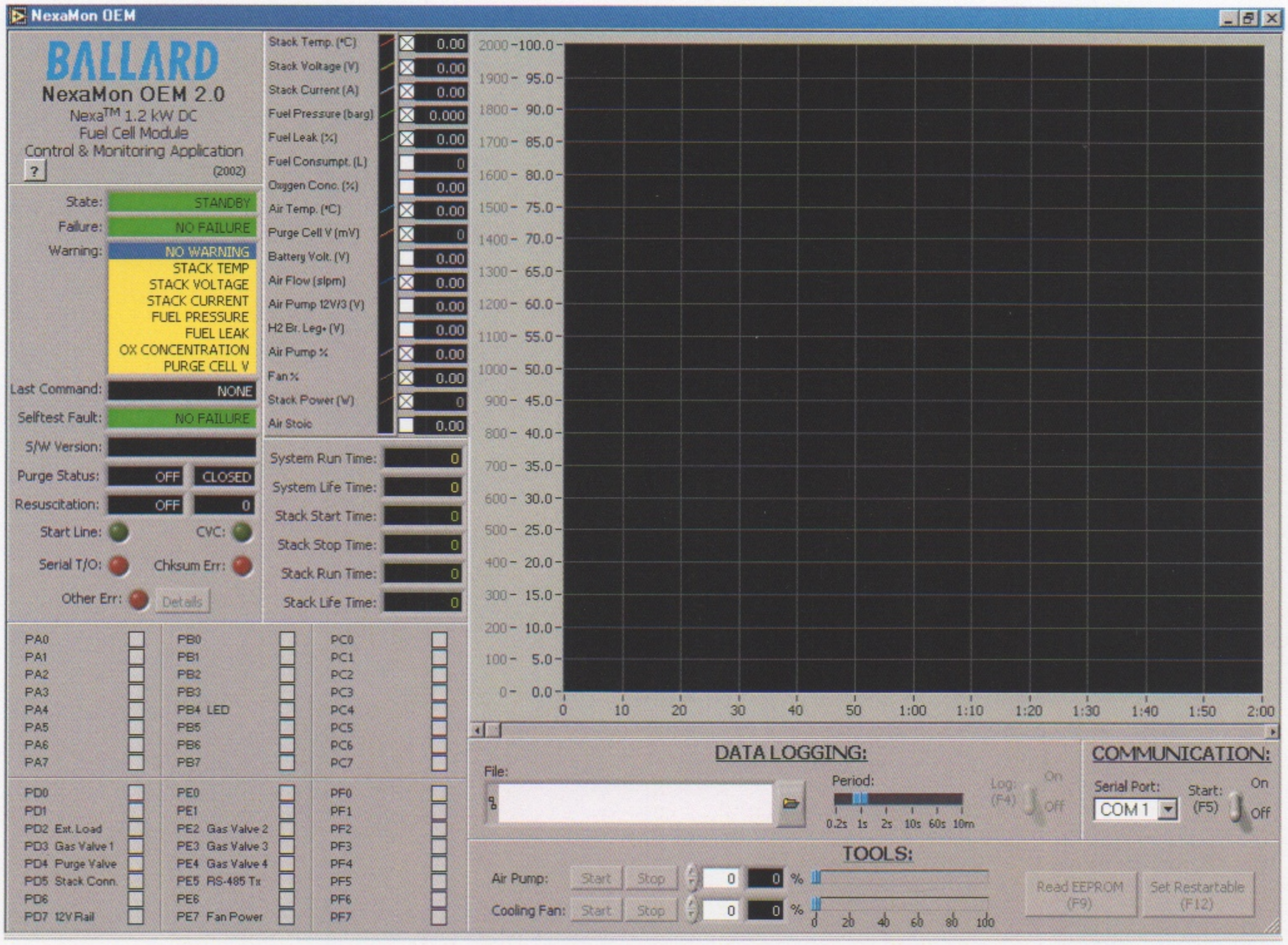
To start the NexaMon OEM program, double-click on the NexamonOEM.exe file within Windows Explorer, or select Start/Programs/NexaMon OEM/NexaMon OEM from the Windows Start menu. Alternatively, create a shortcut of the executable file and move it to your desktop. Double-click on the icon to start the NexaMon OEM software.

To close the NexaMon OEM program, click on the X in the top right hand corner of the main screen.

In order to establish effective communications with the Nexa™ module and computer, the NexaMon OEM software must have control of the serial port. Other devices (such as PDA's) may have software installed that also takes control of the serial port when in use, and these devices can interfere with the NexaMon OEM communications. Be aware of other software programs on your computer that utilise and configure the serial port and avoid conflicts with the NexaMon OEM software.

4.2.3 Main Screen

The main screen of the NexaMon OEM software is illustrated in Figure 14. The main screen is the user interface through which all Nexa™ data monitoring, logging, diagnostics and system control functions are accessed. A description of the software interface and basic functions is provided in this manual.



NexaMon OEM 2.0
Nexa™ 1.2 kW DC
Fuel Cell Module
Control & Monitoring Application
(2002)

State: STANDBY
Failure: NO FAILURE
Warning: NO WARNING
STACK TEMP
STACK VOLTAGE
STACK CURRENT
FUEL PRESSURE
FUEL LEAK
OX CONCENTRATION
PURGE CELL V
Last Command: NONE
Selftest Fault: NO FAILURE
S/W Version:
Purge Status: OFF CLOSED
Resuscitation: OFF 0

Stack Temp. (°C)	☒	0.00
Stack Voltage (V)	☒	0.00
Stack Current (A)	☒	0.00
Fuel Pressure (barg)	☒	0.000
Fuel Leak (%)	☒	0.00
Fuel Consumpt. (L)	☐	0
Oxygen Conc. (%)	☐	0.00
Air Temp. (°C)	☒	0.00
Purge Cell V (mV)	☒	0
Battery Volt. (V)	☐	0.00
Air Flow (slpm)	☒	0.00
Air Pump 12V/3 (V)	☐	0.00
H2 Br. Leg+ (V)	☐	0.00
Air Pump %	☒	0.00
Fan %	☒	0.00
Stack Power (W)	☒	0
Air Stoic	☐	0.00

System Run Time: 0
System Life Time: 0
Stack Start Time: 0
Stack Stop Time: 0
Stack Run Time: 0
Stack Life Time: 0

Serial Port: COM 1

Air Pump: 0 0 %
Cooling Fan: 0 0 %

Figure 14: NexaMon OEM™ Main Screen

Opening the NexaMon OEM software does not engage the Nexa™ module in any way, nor does it initiate serial communications with the unit. To initiate serial communications and receive real-time data updates from the Nexa™ module, one must toggle the Communication Start Switch (F5). The monitoring, logging and diagnostic features of the NexaMon OEM software are only available when the Communication Start Switch has been toggled to the ON position.

4.2.4 Status Fields

The Nexa™ Status Fields, located in the upper left-hand corner of the Main Screen, indicate the operating state of the power module, warning and failure codes, as well as control system settings during operation. A description of each field is provided.

Nexa™ State Field - Indicates the current operating state of the power module, which may include any one of the following system states:

- Standby - The Nexa™ system is in Standby when power is being supplied to the control board from an external power supply or battery, but a start signal has not been applied.
- Starting - When a start signal is applied, the Nexa™ system enters the Starting State. The cooling fan and the air pump are started and the solenoid valve isolating fuel supply is opened to create stack voltage. During the start-up sequence, stack performance, sensor readings and operating conditions are monitored and evaluated against permissive criteria to determine if the system is capable of running. If any of the start-up criteria are not met during the Starting sequence, the system fails (Start Time Expired) and flags the Nexa™ State Field accordingly.
- Running - After the start-up criteria are met, the Nexa™ power module enters the Running State and power may be drawn from the unit. At this point, the Nexa™ controller closes the external relay that connects the fuel cell module to load.
- Warning - A Warning State is issued if any of the fuel cell system operating parameters fall outside of a desired range. The Nexa™ module will still operate and produce power during a warning. Refer to the Warning Status Field description for details.
- Stopping – If the start signal is removed, the Nexa™ module goes through its normal shutdown procedure. Hydrogen is vented from the fuel cell stack to remove water from the anode flow channels. The air pump blows product water from the cathode side of the fuel cells for storage. After, the cathode air and cooling air supply are stopped, and the hydrogen solenoid and purge valves are closed to isolate the stack.
- Failure - A Failure State is issued if any of the fuel cell system operating parameters fall outside of a permitted range. If this occurs, the Nexa™ module shuts down immediately. The system remains in the Failure State until it is returned to Standby by removing the start signal. Refer to the Failure Status Field description for details.
- Non-Restartable – In most cases, failures are resettable by removing the start signal, returning the Nexa™ module to Standby mode and starting again. However, for safety reasons, certain types of failures (hydrogen leaks, software faults & self-test faults) are defined as Non-Restartable. If any of these faults occur, the system is put into a Non-Restartable State and cannot be restarted by simply toggling the start signal. The Non-Restartable State persists until it is cleared using the diagnostic software features provided by NexaMon OEM, with the assistance of Ballard Customer Service.

Failure Status Field - Indicates the kind of failure that has occurred after the Nexa™ module has been put into the Failure State. Types of failures include: No Failure, High Stack Temperature, Low Stack Voltage, High Stack Current, Low Cell Voltage, Low Fuel Pressure, Fuel Leak, Low Oxygen Concentration, Low Air Temperature, Low Purge Cell, Low Battery

Voltage, Start Time Expired, Self-Test Fault and Software Fault. Refer to Table 14 for the failure alarm limits of the NexaTM power module.

Warning Status Field - Indicates the kind of warning that is occurring when the NexaTM module is in the Warning State. Types of warnings include: No Warning, Stack Temperature, Stack Voltage, Stack Current, Fuel Pressure, Fuel Leak, Oxygen Concentration and Purge Cell Voltage Warning. Multiple warnings can be displayed concurrently. Refer to Table 14 for the warning alarm limits of the NexaTM power module.

Parameter	Warning Level	Failure Level	Restartable
Fuel Cell Stack Temperature	> 71 °C	> 73 °C	Yes
Fuel Cell Stack Voltage	< 23 Volts	< 18 Volts	Yes
Fuel Cell Stack Current	> 60 Amps	> 70 Amps	Yes
Cell Voltage Checker	N/A	0.85 V/cell pair	Yes
Hydrogen Pressure	< 1.0 barg	< 0.5 barg	Yes
Hydrogen Concentration	80%	100% (10,000 ppm)	No
Oxygen Concentration	< 19.5%	< 18.7%	Yes
Ambient Temperature	N/A	< 3 °C (start-up)	Yes
Battery Voltage	N/A	< 18 Volts (start-up)	Yes
Purge Cell Voltage	1.0 Volts	0.8 Volts	Yes
System Time-out during Start-up	N/A	Digital	Yes
Self Test Fault	N/A	Digital	No
Software Fault	N/A	Digital	No

Table 14: Warning and Failure Alarm Limits

Last Command - Indicates the last serial (RS-485) command received by the NexaTM power module.

Self-Test Fault - If a Self-Test Fault has occurred, this field will indicate the kind of Self-Test Fault that has happened.

S/W Version - Indicates the software version installed on the NexaTM power module controller.

Purge Status - Displays the status of the fuel purge control system (Off, On or Disabled) and (Open or Closed).

Resuscitation - Shows the fuel cell resuscitation status (Off or On) and the total number of resuscitations. Resuscitations are automatically initiated by the NexaTM control system in response to low cell voltages and restore fuel cell performance.

4.2.5 Status Lights

The following status lights are displayed on the Nexamon OEM Main Screen.

- The green Start Line light comes on when the start line has been activated. The start line indicates that the Nexa™ power module has been signalled to start.
- The green Cell Voltage Check light comes on when the voltages of the individual fuel cells are high enough for proper operation.
- The red Serial Timeout light comes on when there is a problem with the serial inputs or outputs, such as when the communications connector is unplugged or the data transfer is too slow.
- The red Checksum Error light comes on when there is a checksum error in serial communication from the Nexa™ power module, indicating poor communications.
- The Other Error light is for all other errors. An error message will be displayed once but the error light will remain on as long as the problem persists. Click "Details" to view more information about the error.

4.2.6 Process Variables

The NexaMon OEM software monitors 17 key process parameters of the Nexa™ power module, when the Communication Start Switch in the Main Screen has been toggled to the ON positioin. During system operation, the real-time process values are indicated in the parameter field, and the chart plots the progress of those variables that are checked. The monitored process variables are:

- Stack Temperature
- Stack Voltage
- Stack Gross Current (including parasitic loads internal to the power module)
- Fuel Pressure (entering the power module upstream of the inlet pressure regulator)
- Percentage of Fuel Leak Alarm (where 100% indicates 10,000 ppm or 25% LFL of hydrogen in air)
- Fuel Consumption (relative to start of run)
- Oxygen Concentration in the ambient air (as measured in the vicinity of the controller)
- Ambient Air Temperature (as measured in the vicinity of the controller)
- Purge Cell Voltage
- Battery Voltage (used to start the power module)
- Process Air-Flow (as measured by the mass flow meter)
- Air Pump Operating Voltage
- Hydrogen Concentration Bridge Voltage
- Process Air Pump Duty Cycle
- Cooling Air Fan Duty Cycle
- Stack Gross Power (calculated from current and voltage measurements)
- Air-Flow Stoichiometry (calculated from the air mass flow and the current draw)

4.2.7 Chart

The chart plots the progress of the checked process variables. The chart line colour for each process variable is shown beside the process variable name. Turn the process variable chart lines on or off by clicking on the check box beside the variable's name. The check box state does not affect the information that is logged to disk.

The X-axis represents time in seconds and has a default range of two minutes. Alter the range by selecting the rightmost or leftmost value and entering a new value. Use the mouse to zoom in to an X-axis location.

The Y-axis represents the values of all the process variables. The grey Y-axis scale corresponds to the grey process variable fields, and the black scale corresponds to the black process variable fields. You can alter either scale by selecting either the top-most or bottom-most value, and entering a new value.

4.2.8 Time Field

The following time fields are displayed in the Main Screen of NexaMon OEM.

- System Runtime is the time since battery power was applied to the Nexa™ power module.
- System Lifetime is the total time that battery power has been applied to the Nexa™ power module.
- Stack Start Time is the time taken for the most recent startup of the Nexa™ power module.
- Stack Stop Time is the time taken for the most recent shutdown of the Nexa™ power module.
- Stack Runtime is the time since the Nexa™ power module was last successfully started, or the total time the system was most recently run for.
- Stack Lifetime is the total time the Nexa™ power module has been in the running or warning states.

The format of all time fields is hh:mm:ss.

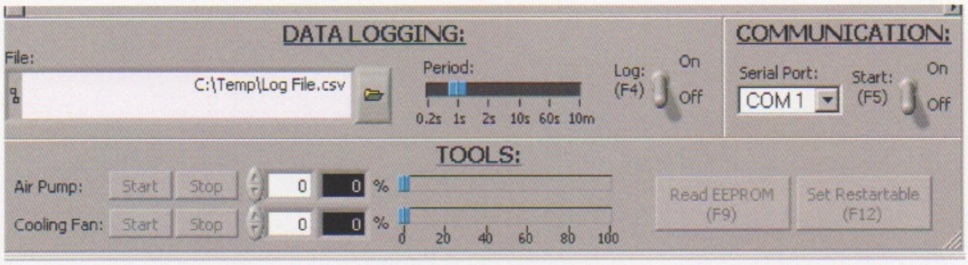
4.2.9 Data Logging

The data logging facility provides real-time sensor and status data, as measured by the Nexa^{TM} power module controller. All process variable values are logged, when the logging feature is turned on, whether they appear on the chart or not. This data can be viewed in graphical form on the host computer.

Figure 15 illustrates how configure a data log file using NexaMon OEM.

- The Data Logging File field shows the name of the file that the data is being saved to.
- The Period slider allows you to choose a data download interval of between 0.2 seconds and 10 minutes. The one-second interval is the default logging interval the first time NexaMon OEM is run. The logging period is stored when NexaMon OEM is closed.
- The Logging switch allows you to turn the data logging function on and off.

Click the Browse button to select a file name. A dialogue box will appear, which will allow you to enter the desired name and path for the stored data file. The file is automatically saved in the comma separated variable (CSV) format and can be easily imported into a spreadsheet program, such as Microsoft Excel. To change the data logging filename or directory, click the mouse cursor on the button right of the data logging name field. You can then enter a new filename and/or choose a different file path.


File: C:\Temp\Log File.csv

Serial Port: COM 1

Air Pump: 0 0 %

Cooling Fan: 0 0 %

Figure 15: Configuring a Data Log File

☞ **NOTE: The power module sensors are used for system control and safety and may not provide accurate performance data. When possible, use calibrated external sensors to measure system data.**

The data logging files contain all of the information displayed on the Main Screen of NexaMon OEM, as illustrated in Figure 14. The data logging files also contain additional internal signal data for Ballard Power Systems use only. Each parameter and its associated unit of measure is detailed in Table 15.

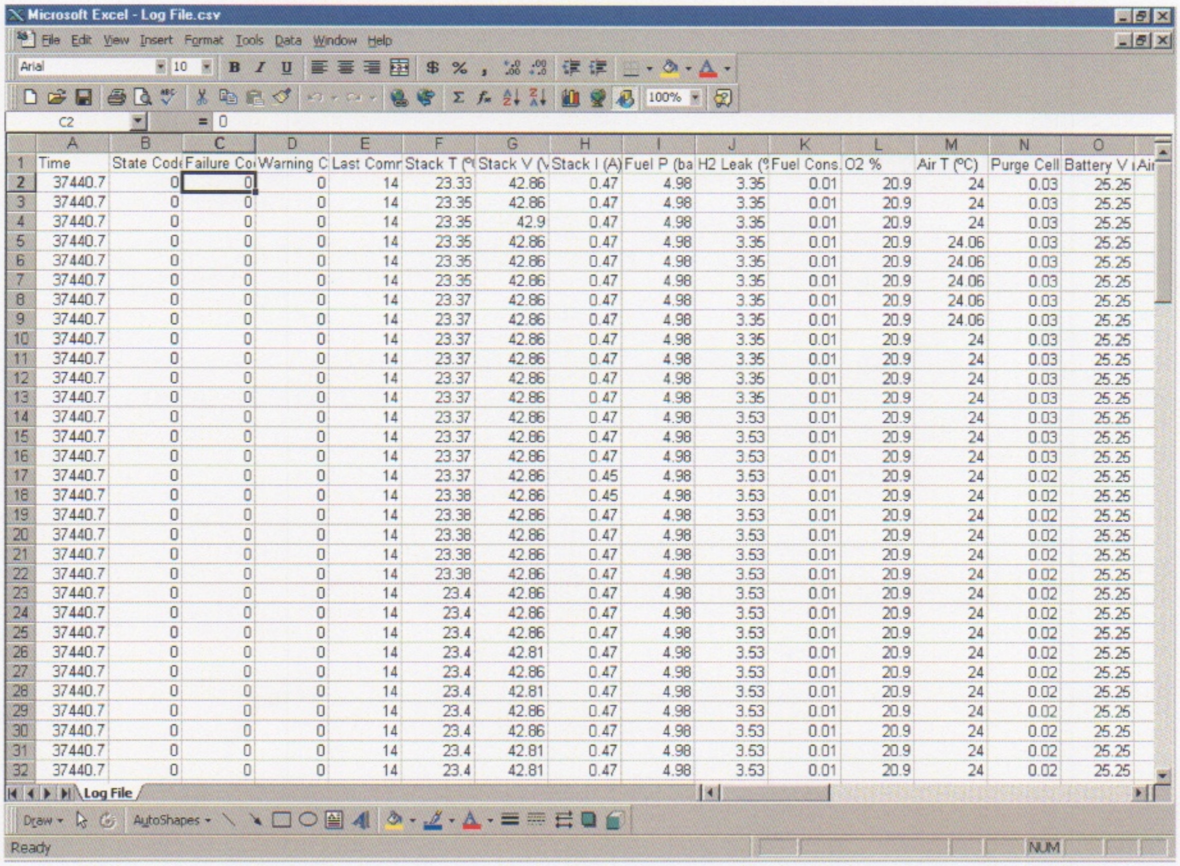
Parameter	Units
Time	*MS Excel Time Format – The number of days since Jan 1, 1900.*
State Code (a.k.a. "Nexa™ status")	0 = Standby 1 = Starting 2 = Running 3 = Warning 4 = Stopping 5 = Failing 6 = Non-Restartable
Failure Code (a.k.a. "Failure status")	*0 = Normal Operation* *1 = High Fuel Cell Stack Temperature* *2 = Low Fuel Cell Stack Voltage* *3 = High Fuel Cell Stack Current* *4 = Low Cell Voltage* *5 = Low Fuel Pressure* *6 = Fuel Leak Detected* *7 = Low Oxygen Concentration* *8 = Low Ambient Temperature* *9 = Low Purge Cell Voltage* *10 = Low Battery Voltage* *11 = Startup Time Expired* *12 = Self Test Fault* *13 = Software Fault*
Warning Code (a.k.a. "Warning status")	1 byte, additive: *0 = No Warnings* *1 = High Fuel Cell Stack Temp. Warning* *2 = Low Fuel Cell Stack Voltage Warning* *4 = High Fuel Cell Stack Current Warning* *8 = Low Fuel Pressure Warning* *16 = Fuel Leak Warning* *32 = Low Oxygen Concentration Warning* *64 = Low Purge Cell Voltage Warning*
Last Command	(Ballard use only)
Stack (Air Exhaust) Temperature	°C
Stack Voltage	*V*
Stack Current	*A (gross)*
Fuel Pressure	*barg*
Fuel Leak (Hydrogen Concentration)	% Alarm (100% = 1% H2)
Fuel Consumption	*L*
Oxygen Concentration	%
Air (Ambient) Temperature	°C
Purge Cell Voltage	V

Parameter	Units
Battery Voltage	VDC
(Process) Air Flow	SLPM
Air Pump 12/3 Operating Voltage	VDC
(Hydrogen Sensor) Bridge Voltage	VDC
(Process) Air Pump Duty Cycle	%
(Cooling Air) Fan Duty Cycle	%
Port A to Port F	(Ballard use only)
Stack Voltage ADC (analog-to-digital conversion)	(Ballard use only)
Stack Current ADC	(Ballard use only)
Fuel Pressure ADC	(Ballard use only)
Purge Cell ADC	(Ballard use only)
Stack Temperature ADC	(Ballard use only)
Oxygen Percentage ADC	(Ballard use only)
Air Flow ADC	(Ballard use only)
Ambient Temperature ADC	(Ballard use only)
Battery Voltage ADC	(Ballard use only)
Fuel (H2) Leak ADC	(Ballard use only)
Bridge Voltage ADC	(Ballard use only)
12/3 Voltage ADC	(Ballard use only)
DAC A Loop ADC	(Ballard use only)
DAC B Loop ADC	(Ballard use only)
Spare ADC	(Ballard use only)
Ground ADC	(Ballard use only)
Pump DAC (digital-to-analog conversion)	(Ballard use only)
Fan DAC	(Ballard use only)
System Run Time	Seconds
System Life Time	Seconds
Stack Start Time	Seconds
Stack Stop Time	Seconds
Stack Run Time	Seconds
Stack Life Time	Seconds
Self Test (Fault)	(Ballard use only)
Parameter	**Units**

Purge (Status)	*0 = CLOSED* *1 = OPEN* *2 = DISABLED*
Resuscitation Status	0 = OFF 1 = ON 2 = DISABLED
Resuscitation Number (over the lifetime of the power module)	# (ASCII Text)
Start Line (status light)	0 = OFF 1 = ON
Cell Voltage Check (status light)	*0 = OFF* *1 = ON*

Table 15: NexaMon OEM Data Logging Format

A portion of a sample data-logging file is illustrated below. Each row corresponds to a single time stamp. Each column of the data table corresponds to the parameters listed in Table 15.


Microsoft Excel - Log File.csv
File Edit View Insert Format Tools Data Window Help
Arial
10
100%
C2
= 0
Log File
Draw
AutoShapes
Ready
NUM

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	
1	Time	State Cod	Failure Co	Warning C	Last Comr	Stack T (º	Stack V (V	Stack I (A)	Fuel P (ba	H2 Leak (%	Fuel Cons.	O2 %	Air T (ºC)	Purge Cell	Battery V	Air
2	37440.7	0	0	0	14	23.33	42.86	0.47	4.98	3.35	0.01	20.9	24	0.03	25.25	
3	37440.7	0	0	0	14	23.35	42.86	0.47	4.98	3.35	0.01	20.9	24	0.03	25.25	
4	37440.7	0	0	0	14	23.35	42.9	0.47	4.98	3.35	0.01	20.9	24	0.03	25.25	
5	37440.7	0	0	0	14	23.35	42.86	0.47	4.98	3.35	0.01	20.9	24.06	0.03	25.25	
6	37440.7	0	0	0	14	23.35	42.86	0.47	4.98	3.35	0.01	20.9	24.06	0.03	25.25	
7	37440.7	0	0	0	14	23.35	42.86	0.47	4.98	3.35	0.01	20.9	24.06	0.03	25.25	
8	37440.7	0	0	0	14	23.37	42.86	0.47	4.98	3.35	0.01	20.9	24.06	0.03	25.25	
9	37440.7	0	0	0	14	23.37	42.86	0.47	4.98	3.35	0.01	20.9	24.06	0.03	25.25	
10	37440.7	0	0	0	14	23.37	42.86	0.47	4.98	3.35	0.01	20.9	24	0.03	25.25	
11	37440.7	0	0	0	14	23.37	42.86	0.47	4.98	3.35	0.01	20.9	24	0.03	25.25	
12	37440.7	0	0	0	14	23.37	42.86	0.47	4.98	3.35	0.01	20.9	24	0.03	25.25	
13	37440.7	0	0	0	14	23.37	42.86	0.47	4.98	3.35	0.01	20.9	24	0.03	25.25	
14	37440.7	0	0	0	14	23.37	42.86	0.47	4.98	3.53	0.01	20.9	24	0.03	25.25	
15	37440.7	0	0	0	14	23.37	42.86	0.47	4.98	3.53	0.01	20.9	24	0.03	25.25	
16	37440.7	0	0	0	14	23.37	42.86	0.47	4.98	3.53	0.01	20.9	24	0.03	25.25	
17	37440.7	0	0	0	14	23.37	42.86	0.45	4.98	3.53	0.01	20.9	24	0.02	25.25	
18	37440.7	0	0	0	14	23.38	42.86	0.45	4.98	3.53	0.01	20.9	24	0.02	25.25	
19	37440.7	0	0	0	14	23.38	42.86	0.47	4.98	3.53	0.01	20.9	24	0.02	25.25	
20	37440.7	0	0	0	14	23.38	42.86	0.47	4.98	3.53	0.01	20.9	24	0.02	25.25	
21	37440.7	0	0	0	14	23.38	42.86	0.47	4.98	3.53	0.01	20.9	24	0.02	25.25	
22	37440.7	0	0	0	14	23.38	42.86	0.47	4.98	3.53	0.01	20.9	24	0.02	25.25	
23	37440.7	0	0	0	14	23.4	42.86	0.47	4.98	3.53	0.01	20.9	24	0.02	25.25	
24	37440.7	0	0	0	14	23.4	42.86	0.47	4.98	3.53	0.01	20.9	24	0.02	25.25	
25	37440.7	0	0	0	14	23.4	42.86	0.47	4.98	3.53	0.01	20.9	24	0.02	25.25	
26	37440.7	0	0	0	14	23.4	42.81	0.47	4.98	3.53	0.01	20.9	24	0.02	25.25	
27	37440.7	0	0	0	14	23.4	42.86	0.47	4.98	3.53	0.01	20.9	24	0.02	25.25	
28	37440.7	0	0	0	14	23.4	42.81	0.47	4.98	3.53	0.01	20.9	24	0.02	25.25	
29	37440.7	0	0	0	14	23.4	42.86	0.47	4.98	3.53	0.01	20.9	24	0.02	25.25	
30	37440.7	0	0	0	14	23.4	42.86	0.47	4.98	3.53	0.01	20.9	24	0.02	25.25	
31	37440.7	0	0	0	14	23.4	42.81	0.47	4.98	3.53	0.01	20.9	24	0.02	25.25	
32	37440.7	0	0	0	14	23.4	42.81	0.47	4.98	3.53	0.01	20.9	24	0.02	25.25	

Figure 16: Sample of Data Logging File

4.2.10 Read EEPROM

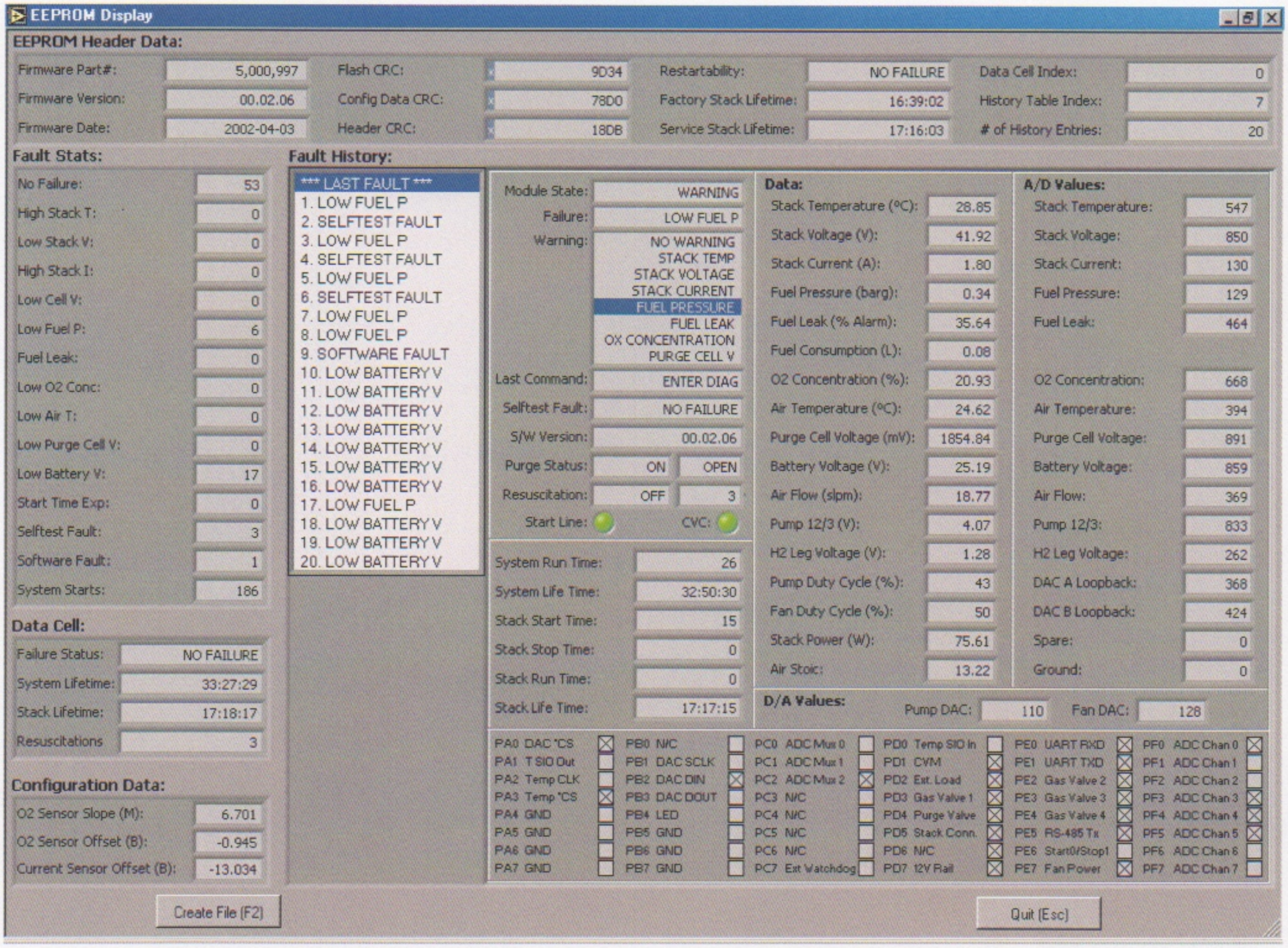
The diagnostic data download facility reads the contents of the Nexa™ power module controller's non-volatile "electronically erasable programmable read-only memory" (or "EEPROM"). This data can be viewed on the host computer's monitor and stored in a file for further assessment.

The power module's EEPROM stores the following information:

- EEPROM Header Data — this contains factory information pertaining to the controller hardware and software
- Fault Statistics — this contains a record of the total number of each type of alarm
- Configuration Data — this contains oxygen and current sensor calibration data
- Cumulative System Data Cell — this contains overall lifetime and other cumulative information
- Last Fault Status Data — this contains detailed information pertaining to the last fault that occurred. Data includes operating state settings, system (process variable) data, port configuration, analogue-to-digital conversion values, and time information.
- Historical Fault Data — this contains information pertaining to the last 20 faults that have occurred. This data is less detailed than the last fault status data. Specific data includes operating state settings, time information, and system (process variable) data. The historical fault data is accessed by clicking on a fault in the fault list (see below.)

To retrieve the diagnostic data:

1. Connect the computer to the Nexa™ module, using the communication wiring harness, as illustrated in the previous section.
2. Start the NexaMon OEM software program.
3. Provide 24VDC to the Nexa control board using a power supply or battery, as illustrated in the previous section. Establish communications between the Nexa™ module and computer by toggling the Communication Start Switch to the ONB position on the main screen. The Nexa™ system should be in Standby State.
4. Press on the Read **EEPROM** button (F9) on the main screen. The last fault data screen appears, as shown in Figure 17.



EEPROM Header Data:

Firmware Part#: 5,000,997
Firmware Version: 00.02.06
Firmware Date: 2002-04-03
Flash CRC: 9D34
Config Data CRC: 78D0
Header CRC: 18DB
Restartability: NO FAILURE
Factory Stack Lifetime: 16:39:02
Service Stack Lifetime: 17:16:03
Data Cell Index: 0
History Table Index: 7
# of History Entries: 20

Fault Stats:

No Failure: 53
High Stack T: 0
Low Stack V: 0
High Stack I: 0
Low Cell V: 0
Low Fuel P: 6
Fuel Leak: 0
Low O2 Conc: 0
Low Air T: 0
Low Purge Cell V: 0
Low Battery V: 17
Start Time Exp: 0
Selftest Fault: 3
Software Fault: 1
System Starts: 186

Data Cell:

Failure Status: NO FAILURE
System Lifetime: 33:27:29
Stack Lifetime: 17:18:17
Resuscitations 3

Configuration Data:

O2 Sensor Slope (M): 6.701
O2 Sensor Offset (B): -0.945
Current Sensor Offset (B): -13.034

Fault History:

*** LAST FAULT ***
1. LOW FUEL P
2. SELFTEST FAULT
3. LOW FUEL P
4. SELFTEST FAULT
5. LOW FUEL P
6. SELFTEST FAULT
7. LOW FUEL P
8. LOW FUEL P
9. SOFTWARE FAULT
10. LOW BATTERY V
11. LOW BATTERY V
12. LOW BATTERY V
13. LOW BATTERY V
14. LOW BATTERY V
15. LOW BATTERY V
16. LOW BATTERY V
17. LOW FUEL P
18. LOW BATTERY V
19. LOW BATTERY V
20. LOW BATTERY V

Module State: WARNING
Failure: LOW FUEL P
Warning: NO WARNING
STACK TEMP
STACK VOLTAGE
STACK CURRENT
FUEL PRESSURE
FUEL LEAK
OX CONCENTRATION
PURGE CELL V
Last Command: ENTER DIAG
Selftest Fault: NO FAILURE
S/W Version: 00.02.06
Purge Status: ON OPEN
Resuscitation: OFF 3
Start Line: ● CVC: ●

System Run Time: 26
System Life Time: 32:50:30
Stack Start Time: 15
Stack Stop Time: 0
Stack Run Time: 0
Stack Life Time: 17:17:15

Data:

Stack Temperature (°C): 28.85
Stack Voltage (V): 41.92
Stack Current (A): 1.80
Fuel Pressure (barg): 0.34
Fuel Leak (% Alarm): 35.64
Fuel Consumption (L): 0.08
O2 Concentration (%): 20.93
Air Temperature (°C): 24.62
Purge Cell Voltage (mV): 1854.84
Battery Voltage (V): 25.19
Air Flow (slpm): 18.77
Pump 12/3 (V): 4.07
H2 Leg Voltage (V): 1.28
Pump Duty Cycle (%): 43
Fan Duty Cycle (%): 50
Stack Power (W): 75.61
Air Stoic: 13.22

A/D Values:

Stack Temperature: 547
Stack Voltage: 850
Stack Current: 130
Fuel Pressure: 129
Fuel Leak: 464
O2 Concentration: 668
Air Temperature: 394
Purge Cell Voltage: 891
Battery Voltage: 859
Air Flow: 369
Pump 12/3: 833
H2 Leg Voltage: 262
DAC A Loopback: 368
DAC B Loopback: 424
Spare: 0
Ground: 0

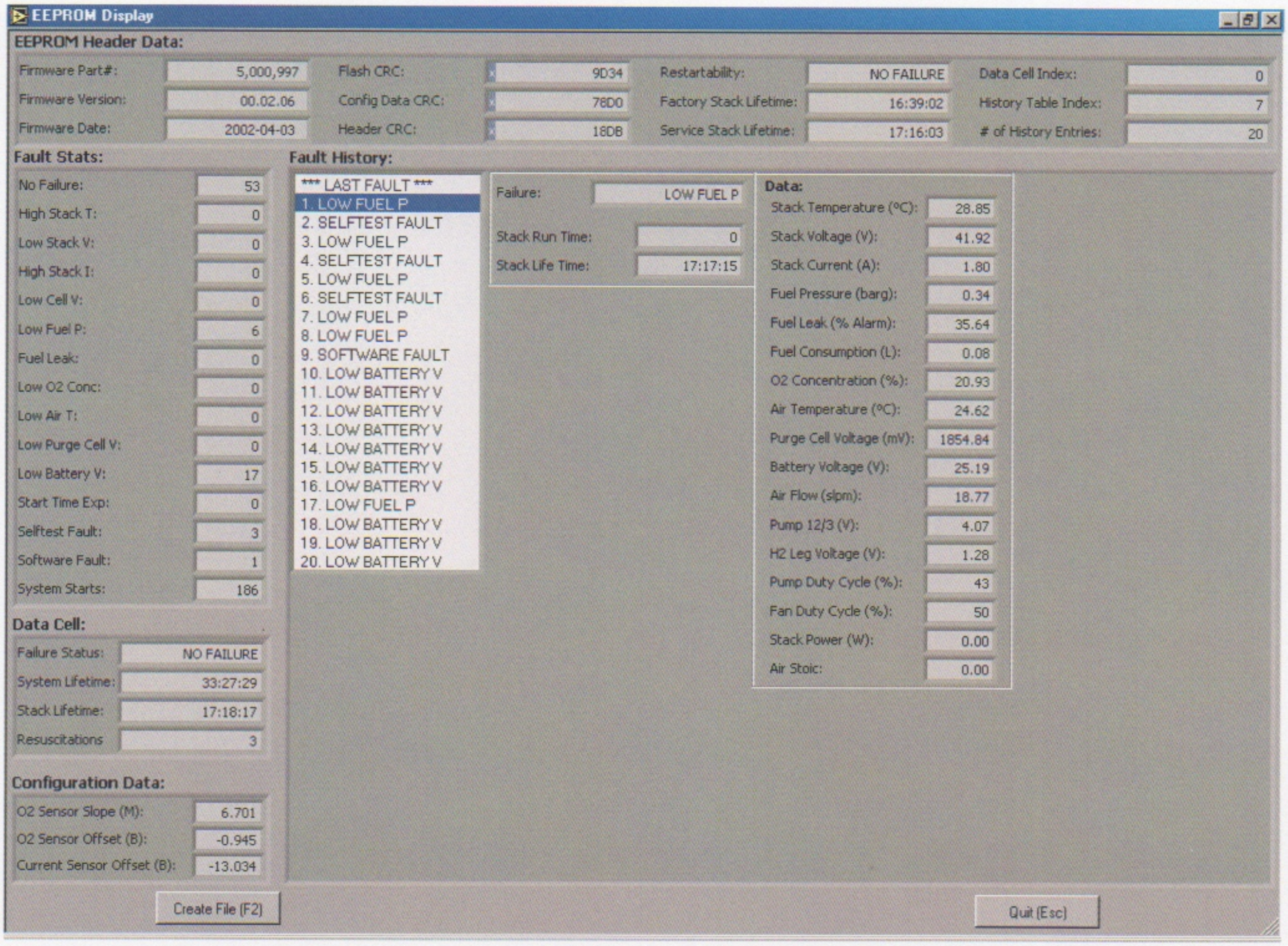
D/A Values: Pump DAC: 110 Fan DAC: 128

PA0	DAC 'CS	☒	PB0	N/C	☐	PC0	ADC Mux 0	☐	PD0	Temp SIO In	☐	PE0	UART RXD	☒	PF0	ADC Chan 0	☒
PA1	T SIO Out	☐	PB1	DAC SCLK	☐	PC1	ADC Mux 1	☐	PD1	CVM	☒	PE1	UART TXD	☒	PF1	ADC Chan 1	☐
PA2	Temp CLK	☐	PB2	DAC DIN	☒	PC2	ADC Mux 2	☒	PD2	Ext. Load	☒	PE2	Gas Valve 2	☒	PF2	ADC Chan 2	☐
PA3	Temp 'CS	☒	PB3	DAC DOUT	☐	PC3	N/C	☐	PD3	Gas Valve 1	☒	PE3	Gas Valve 3	☒	PF3	ADC Chan 3	☒
PA4	GND	☐	PB4	LED	☐	PC4	N/C	☐	PD4	Purge Valve	☒	PE4	Gas Valve 4	☒	PF4	ADC Chan 4	☒
PA5	GND	☐	PB5	GND	☐	PC5	N/C	☐	PD5	Stack Conn.	☒	PE5	RS-485 Tx	☒	PF5	ADC Chan 5	☒
PA6	GND	☐	PB6	GND	☐	PC6	N/C	☐	PD6	N/C	☒	PE6	Start0/Stop1	☐	PF6	ADC Chan 6	☐
PA7	GND	☐	PB7	GND	☐	PC7	Ext Watchdog	☐	PD7	12V Rail	☒	PE7	Fan Power	☒	PF7	ADC Chan 7	☐

Figure 17: Sample of Last Fault Data Screen

5. To view one of the 20 previous faults, click on the desired fault on the fault list. The header and sidebar items remain the same, and the fault history shows the historical fault data, as

shown in Figure 18. This screen is similar to the last fault screen but only contains information pertaining to the selected fault.



EEPROM Header Data:

Firmware Part#: 5,000,997
Firmware Version: 00.02.06
Firmware Date: 2002-04-03
Flash CRC: 9D34
Config Data CRC: 78D0
Header CRC: 18DB
Restartability: NO FAILURE
Factory Stack Lifetime: 16:39:02
Service Stack Lifetime: 17:16:03
Data Cell Index: 0
History Table Index: 7
# of History Entries: 20

Fault Stats:

No Failure: 53
High Stack T: 0
Low Stack V: 0
High Stack I: 0
Low Cell V: 0
Low Fuel P: 6
Fuel Leak: 0
Low O2 Conc: 0
Low Air T: 0
Low Purge Cell V: 0
Low Battery V: 17
Start Time Exp: 0
Selftest Fault: 3
Software Fault: 1
System Starts: 186

Fault History:

*** LAST FAULT ***
1. LOW FUEL P
2. SELFTEST FAULT
3. LOW FUEL P
4. SELFTEST FAULT
5. LOW FUEL P
6. SELFTEST FAULT
7. LOW FUEL P
8. LOW FUEL P
9. SOFTWARE FAULT
10. LOW BATTERY V
11. LOW BATTERY V
12. LOW BATTERY V
13. LOW BATTERY V
14. LOW BATTERY V
15. LOW BATTERY V
16. LOW BATTERY V
17. LOW FUEL P
18. LOW BATTERY V
19. LOW BATTERY V
20. LOW BATTERY V

Failure: LOW FUEL P
Stack Run Time: 0
Stack Life Time: 17:17:15

Data:

Stack Temperature (°C): 28.85
Stack Voltage (V): 41.92
Stack Current (A): 1.80
Fuel Pressure (barg): 0.34
Fuel Leak (% Alarm): 35.64
Fuel Consumption (L): 0.08
O2 Concentration (%): 20.93
Air Temperature (°C): 24.62
Purge Cell Voltage (mV): 1854.84
Battery Voltage (V): 25.19
Air Flow (slpm): 18.77
Pump 12/3 (V): 4.07
H2 Leg Voltage (V): 1.28
Pump Duty Cycle (%): 43
Fan Duty Cycle (%): 50
Stack Power (W): 0.00
Air Stoic: 0.00

Data Cell:

Failure Status: NO FAILURE
System Lifetime: 33:27:29
Stack Lifetime: 17:18:17
Resuscitations 3

Configuration Data:

O2 Sensor Slope (M): 6.701
O2 Sensor Offset (B): -0.945
Current Sensor Offset (B): -13.034

Figure 18: Sample of Historical Fault Data Screen

6. Press the **CREATE FILE** button, or F2, to store the information to a diagnostic data report. The program prompts you to select or enter a file name and directory. A sample of the diagnostic data report is shown in Figure 19.

7. Press the **CLOSE** button to return to the main screen.

```
EPROM HEADER DATA

Software Part Number            5,000,997
Software Revision ID          00.02.06
Software Build Date           2002-04-03
Software Flash CRC-16           0x9D34
Configuration Data CRC-16         0x78D0
EEPROM Header CRC-16              0x18DB
System Restartability Status    NO FAILURE
Factory Stack Lifetime Stamp     0016:39:02
Service Stack Lifetime Stamp     0017:16:03
Cumulative Time Cell Index       0
History Table Entry Index       7
Number of History Entries       20

CONFIGURATION DATA

O2 Sensor Slope (M)             6.70
O2 Sensor Offset (B)           -0.94
Current Sensor Offset (B)        -13.03

FAULT STATISTICS

Normal Shutdowns              53
HIgh Stack Temperature          0
Low Stack Voltage            0
High Stack Current           0
Low Cell Voltage            0
Low Fuel Pressure            6
Fuel Leak Detected           0
Low Oxygen Concentration         0
Low Ambient Temperature          0
Low Purge Cell Voltage         0
Low Battery Voltage          17
Startup Time Expired          0
Selftest Fault            3
Software Fault             1
Startups/Resets            186

CUMULATIVE SYSTEM DATA CELL

Last Shutdown/Failure Type      NO FAILURE
Total System Lifetime         0033:27:29
Total Stack Lifetime         0017:18:17
Cumulative Resuscitations       3
```

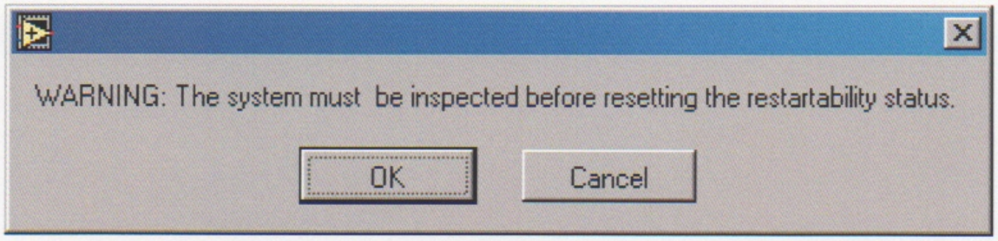
```
LAST FUEL CELL FAULT STATUS DATA

System State at Time of Fault    WARNING
System Fault Type              LOW FUEL P
System Warning Bit Mask          0x04
Last Command Acknowledged        ENTER DIAG
System Selftest Status         NO FAILURE
Purge Status                 ON
Purge Valve                  OPEN
Resuscitation Status           OFF
Total Resuscitations           3
System Start Line Status         ON
Cell Voltage Checking            ON

Stack Temperature (°C):          28.85
Stack Voltage (V):             41.92
Stack Current (A):              1.80
Fuel Pressure (barg):            0.34
Fuel Leak (% Alarm):             35.64
Fuel Consumption (L):             0.08
O2 Concentration (%):            20.93
Air Temperature (°C):            24.62
Purge Cell Voltage (mV):         1854.84
Battery Voltage (V):            25.19
Air Flow (slpm):               18.77
Pump 12/3 (V):                  4.07
H2 Leg Voltage (V):              1.28
Pump Duty Cycle (%):             43.00
Fan Duty Cycle (%):             50.00
Stack Power (W):                75.61
Air Stoic:                   13.22

PORT A                       0x09 (00001001)
PORT B                       0x04 (00000100)
PORT C                       0x04 (00000100)
PORT D                       0xFE (11111110)
PORT E                       0xBF (10111111)
PORT F                       0x39 (00111001)

ADC0 Stack Voltage             850
ADC1 Stack Current             130
ADC2 Fuel Pressure             129
ADC3 Purge Cell Voltage          891
ADC4 Stack Temperature           547
```

```
ADC5 Oxygen Concentration        668
ADC6 Air Flow Rate            369
SPI  Air Temperature Sensor      394
ADC7 MUX0 Battery Voltage        859
ADC7 MUX1 H2 Leak Sensor          464
ADC7 MUX2 H2 Sensor Leg+          262
ADC7 MUX3 12/3 Volt Rail         833
ADC7 MUX4 DAC A Loopback          368
ADC7 MUX5 DAC B Loopback          424
ADC7 MUX6 Spare                  0
ADC7 MUX7 Ground                  0
DACA Air Compressor             110
DACB Cooling Fan              128

Current System Run Time        0000:00:26
Total System Lifetime        0032:50:30
Current Stack Start Time       0000:00:15
Current Stack Stop Time        0000:00:00
Current Stack Run Time         0000:00:00
Total Stack Lifetime         0017:17:15


FAULT HISTORY DATA

(Additional fault list data here for 20 faults total)
```

Figure 19: Sample of Diagnostic Data Report

4.2.11 Set Restartable

Certain faults are non-restartable and must be reset using diagnostic software before the Nexa™ system can be restarted. In NexaMon OEM, the Set Restartable button is used to reset non-restartable faults in the Nexa™ module. If executed, the user will be prompted to verify that the source of the fault has been addressed before continuing. For instance, if the onboard sensor detects a hydrogen leak, the power module will be automatically shut down and placed in a Non-Restartable State. If the user attempts to clear that fault using the NexaMon OEM software, he will be prompted to check that the source of leak has been removed before continuing, as illustrated in Figure 20.



WARNING: The system must be inspected before resetting the restartability status.

Figure 20: Resetting Non-Restartable Faults

If you experience a Non-Restartable Fault with your Nexa™ module and are unsure of the cause, contact Ballard Customer Service for further guidance.

4.2.12 Air Pump and Cooling Fan

Diagnostic tools are included to test the air pump and cooling fan separately. The Start button turns on the pump or the fan according to a preset speed. The Stop button turns off the device. Use the slider bars to adjust the speed of the fan or the pump, or alternatively type in the speed setting ranging from 0 to 100%.

Note that running the air pump when the Nexa™ module is not in operation can cause drying of the fuel cell membranes and reduced system lifetime. When conducting an air pump diagnostic test, minimise the amount of time that the air pump is left running.

4.2.13 Changing the Serial Port

The Serial Port menu allows you to choose a serial communications port from COM 1 to COM 8. The default port is COM 1, when NexaMon OEM is first run. The port state is stored on shutdown. The **Start** switch must be turned off to access the Serial Port menu. The serial port applies to all program communications. The selected port must be the one that is hooked up for system communication. To change the serial port:

1. Set the Start switch (on the main screen) to Off. This enables the serial port menu.
2. Select a serial port by dropping the serial port menu (or by pressing F2) and select the desired COM number, as illustrated in
3. Set the start switch to On. If the selected port is not hooked up, the Serial Timeout light will come on.

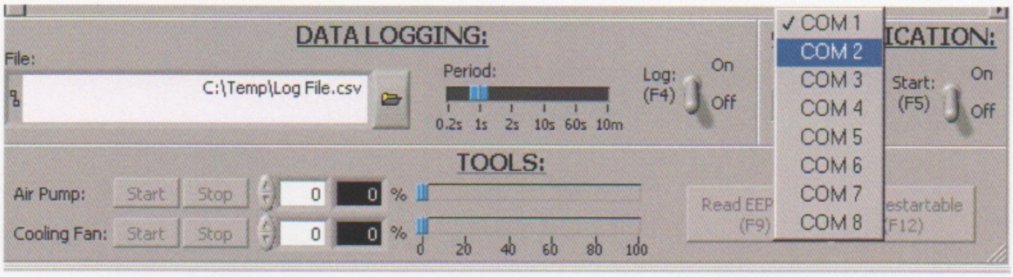


Figure 21: Changing the Serial Port

BALLARD POWER SYSTEMS INC.

- and –

SOFTWARE LICENSE AGREEMENT

SOFTWARE LICENSE AGREEMENT

THIS SOFTWARE LICENSE AGREEMENT (the "Agreement") is made ◆____________________◆, 2002 between **BALLARD POWER SYSTEMS INC.** ("BPS"), a Canadian corporation having an office at 9000 Glenlyon Parkway, Burnaby, British Columbia, Canada, V5J 5J9 and ◆____________________◆, having an office at ◆____◆, (the "Licensee")

WHEREAS

(A) BPS has developed a software product (the "Licensed Product") to be used by OEM's with BPS's 1.2 kW NEXA fuel cell power module (the "NEXA™ Module");

(B) The Licensee needs to use the Licensed Product in order to incorporate the NEXA™ Module into end user systems;

(C) BPS is willing to grant such right to the Licensee on the terms and subject to the conditions herein set forth;

WITNESSES THAT for value received, the parties covenant and agree as follows:

1. DEFINITIONS AND INTERPRETATION

1.1 **Definitions** - In this Agreement, including the recitals, except as otherwise provided or unless the context otherwise requires,

"Business Day" means

> (a) in Vancouver, British Columbia, a day that is not a Saturday, a Sunday or a public holiday, and
>
> (b) in ◆____________________◆, ◆____________________◆, a day that is not a Saturday, a Sunday or a public holiday,

"Data" means the data and other information concerning the NEXA™ Module which arises out of the operation of the Software,

"Documentation" means the user guides and manuals concerning the installation and use of the Licensed Product, howsoever provided,

"Effective Date" means the date on which this Agreement is signed,

"Event of Default" in relation to a party means an event of default arising as a result of such party being subject to, or the subject of, one or more of the following circumstances:

(a) an order is made or a resolution is passed or a petition is filed by such party for the liquidation, dissolution or winding-up of such party,

(b) such party commits a material breach in observing or performing any other material covenant, agreement or condition of this Agreement on its part to be observed or performed and does not rectify or cure such breach within 30 days after receipt of written notice from the other party to this Agreement specifying in detail such breach,

(c) an execution, sequestration or any other process of any court becomes enforceable against such party or any distress or analogous process is levied upon any material part of the property, assets and undertaking of such party and any such process or distress is not stayed or otherwise suspended by a court of competent jurisdiction within 30 days and has, or could have, a material adverse effect on the business or condition, financial or otherwise, of such party,

(d) such party commits an act of bankruptcy, makes an assignment or bulk sale of its assets, is adjudged or declared bankrupt or makes an assignment for the benefit of creditors, consents to a proposal or similar action under any bankruptcy or insolvency legislation applicable to it, or commences any other proceeding relating to it under any reorganization, arrangement, readjustment of debt, dissolution or liquidation law or statute of any jurisdiction whether now or hereafter in effect, or consents to any such proceeding,

(e) a custodian, liquidator, receiver, receiver and manager, receiver-manager, trustee or any other person with similar powers is appointed for such party or in respect of any material property or assets or material part of the property or assets of such party and not discharged within 30 days after its appointment and before any action is taken by it in respect of such property or assets which will materially affect the rights of the parties to this Agreement thereto, and

(f) a final, non-appealable, decision of any judicial, administrative, governmental or other authority or arbitrator is made which enjoins or restrains, or renders illegal or unenforceable, the performance or observance by such party of any material term of this Agreement,

"Force Majeure" means an act of God, strike, lockout or other industrial disturbance, war, blockade, insurrection, riot, earthquake, typhoon, hurricane, flood, fire, explosion or other similar occurrence beyond the reasonable control of a party which prevents such party from performing its obligations under the Agreement,

"Governmental Authority" means, as applicable, the government of Canada, the government of a Canadian province or territory and a ministry, department, commission, board, bureau or other agency of or municipality, regional district or other local governing body established by, any such government,

"Indemnified Claim" has the meaning ascribed to it in §3.1,

"Licensed Product" has the meaning ascribed in Recital A, and includes all Documentation and Updates provided to the Licensee,

"Notice" has the meaning ascribed to it in §5.8,

"Person" means an individual, corporation, body corporate, firm, limited liability company, partnership, syndicate, joint venture, society, association, trust or unincorporated organization or Government Authority or any trustee, executor, administrator or other legal representative,

"Software License" has the meaning ascribed to it in §2.1,

"Update" means a supplemental program that may contain bug fixes or improved program functions for the software comprising the Licensed Product or a subsequent release of the software comprising the Licensed Product,

1.2 **Schedules** - The following schedule is incorporated into this Agreement by reference and forms a part hereof:

Schedule A – Licensed Product

2. LICENSE GRANT

2.1 **License Grant** - BPS hereby grants to the Licensee a non-exclusive, non-transferable, royalty-free, limited right and license (the "Software License") without the right to sublicense the same, to use the Licensed Product solely for the purposes of use in connection with the NEXA™ Module. For greater certainty, the Licensee acknowledges that the Licensed Product is licensed (or leased), not sold, to the Licensee.

2.2 **Certain Limitations** - The license rights granted to the Licensee under this Agreement are limited to computer readable, object code versions of the Licensed Product only. The Licensee will have no access, or any licensed rights, to human readable, source code versions of the Licensed Product or any component thereof.

2.3 **Ownership** - The Licensee acknowledges that all title, copyright and other proprietary rights in, and ownership of, the Licensed Product, including the Documentation, and the Data, regardless of the media upon which the original or any copy may be recorded or fixed, will remain with BPS. The Licensee will not acquire any rights, express or implied, of ownership or otherwise, in the Licensed Product, including the Documentation, and the Data, or any part thereof, other than those expressly granted to the Licensee pursuant to this Agreement.

2.4 **General Restrictions and Covenants** - The Licensee acknowledges and agrees to the following restrictions on the use of the Licensed Product and the Data:

(a) access to the Data is provided solely and exclusively for the internal use of the Licensee. The Licensee will not provide access to the Licensed Product or the Data to any other Person or entity, other than BPS,

(b) the Licensee will cooperate with BPS in protecting the respective copyright and/or any other proprietary rights of BPS in the Data and the Licensed Product,

(c) the Licensee will not sell, transfer, assign, sublicense, rent, lease, loan, publish, distribute, disseminate, disclose or convey, any part of, the Data or the Licensed Product,

(d) the Licensee will not copy, modify, reverse engineer, disassemble, decompile or decrypt the Licensed Product or reconstruct, copy or prepare derivative works based on the Data or any portion thereof, or permit others to perform such actions,

(e) the Licensee will not remove, alter or obscure any proprietary notices on the Licensed Product or the Data or any printed extracts thereof, and

(f) the Licensee will perform each of its obligations under this Agreement in a commercially reasonable manner that preserves and protects the business reputation and the respective proprietary and other rights of BPS in the Licensed Product and the Data.

2.5 **Verification** - Promptly upon BPS's written request, the Licensee will provide BPS with a signed certificate of a senior officer of the Licensee verifying that the Licensed Product is being used in accordance with the provisions of this Agreement. BPS may audit the Licensee's use of the Licensed Product. Any such audit must be conducted during regular business hours at the Licensee's facilities and must not unreasonably interfere with the Licensee's business activities. If any audit reveals that Licensee is using Licensed Product contrary to the terms and limitations of this Agreement, BPS may terminate the Software License without prejudice to any other of BPS's rights.

3. INDEMNITY AND REMEDIES

3.1 **Infringement Indemnity** - Subject to the limitations set forth in §3.5, BPS will defend and indemnify the Licensee against third party claims (each an "Indemnified Claim") that the Licensed Product infringes any copyright enforceable in Canada or the United States or misappropriates any trade secret (as the terms "misappropriation" and "trade secret" are defined in the Uniform Trade Secrets Act) protected under the laws of any states within the United States, provided that

(a) the Licensee notifies BPS in writing within 30 days after the claim,

(b) BPS has sole control of the defense and all related settlement negotiations in connection with such claim, and

(c) the Licensee provides BPS with the assistance, information and authority necessary to perform BPS's obligations under this §3.1.

3.2 **No Liability** - For any claim for infringement for which a defense is not provided in §3.1, BPS, in its sole discretion, may elect to treat such claim as an Indemnified Claim. BPS will have no liability for any claim of infringement based on use of a superseded or altered release of the Licensed Product if the infringement would have been avoided by the use of a current unaltered release of the Licensed Product which was obtainable by the Licensee from BPS. Furthermore, BPS will have no obligation to the Licensee for any claims relating to allegations of copyright infringement which arise outside Canada and the United States or any claims relating to allegations of trade secret misappropriation which arise outside the geographical boundaries of Canada and the United States.

3.3 **BPS Rights on Infringement** - If the Licensed Product is held, or is believed by BPS to infringe, then BPS will have the option, at its expense, to

(a) modify the Licensed Product to be non-infringing, or

(b) obtain for the Licensee a license to continue using the Licensed Product.

If, in BPS's sole discretion, it is not economically or commercially reasonable to perform either of the above options, BPS may terminate the Software License without any further liability to the Licensee. The provisions of §3.1, §3.2 and this §3.3 describe BPS's entire liability and the Licensee's sole and exclusive remedy for infringement.

3.4 **Disclaimer** – BPS does not make any warranties, whether express or implied, including any implied warranties of merchantability and fitness for a particular purpose. No oral or written information or advice given by BPS, its agents or employees will create a warranty.

3.5 **Liability Limitation** - Notwithstanding any provision of this Agreement to the contrary, in no event will BPS be liable for any indirect, incidental, special, punitive or consequential damages or damages for loss of profits, revenue, data or use, incurred by the Licensee, whether in an action in contract or tort, even if BPS has been advised of the possibility of such damages.

4. TERMINATION

4.1 **Termination** - The Software License may be terminated

(a) by either party forthwith upon written notice to that effect if the other party is the subject of, or becomes subject to, an Event of Default, and

(b) by BPS

(i) as provided in §3.3, or

(ii) forthwith upon written notice.

4.2 **Effect of Termination** - Immediately upon termination of the Software License, the Licensee will cease using the Licensed Product, will cease accessing the Data through its computer system, will delete the Licensed Product from its computer, will, at the request of BPS, either return the Licensed Product to BPS or destroy the Licensed Product, including the Documentation, packaging and all reproductions thereof and provide to BPS a certificate of one of its senior officers verifying in writing to BPS the return or destruction, as the case may be, of the Licensed Product and all reproductions thereof. Any termination of the Software License and return or destruction of the Licensed Product will not limit either party from pursuing other remedies available to it, including injunctive relief.

5. GENERAL PROVISIONS

5.1 **Entire Agreement** - This Agreement constitutes the entire agreement between the parties and supersedes every previous agreement, communication, expectation, negotiation, representation or understanding, whether oral or written, express or implied, statutory or otherwise, between the parties with respect to the subject matter of this Agreement.

5.2 **Severability** - If any provision of this Agreement is at any time unenforceable or invalid for any reason it will be severable from the remainder of this Agreement and, in its application at that time, this Agreement will be construed as though such provision was not contained herein and the remainder will continue in full force and effect and be construed as if this Agreement had been executed without the invalid or unenforceable provision.

5.3 **Amendments** - This Agreement may not be amended except in writing signed by the parties.

5.4 **Assignment** – The Licensee may not assign this Agreement or its rights or obligations hereunder except with the prior written consent of BPS, and any purported assignment without such consent will be null and void. BPS will have the unrestricted right to assign this Agreement.

5.5 **Governing Law** - This Agreement for all purposes will be governed exclusively by and construed and enforced in accordance with the laws prevailing in British Columbia, Canada without reference to the provisions of conflict of laws.

5.6 **Attornment** - Each party hereby irrevocably and unconditionally attorns to the exclusive jurisdiction of the courts of British Columbia, Canada, and the courts having appellate jurisdiction thereover for any actions, suits or proceedings arising out of or relating to this Agreement and the transactions contemplated hereby.

5.7 **Notice** - Every notice, request, demand or direction (each, for the purposes of §5.8, §5.9 and §5.10, a "Notice") to be given pursuant to this Agreement must be in writing and must be delivered by hand (e.g. Federal Express or other international courier service) or sent by facsimile transmission or other similar form of written transmission by electronic means, in each case addressed as follows:

(a) If to BPS, at:

9000 Glenlyon Parkway
Burnaby, British Columbia, Canada
V5J 5J9

Telecopier: (604) 412-3131
Attention: Corporate Secretary

(b) If to the Licensee, at:

◆______________________◆
◆______________________◆
◆______________________◆
◆______________________◆

Telecopier: ◆______________◆
Attention: ◆______________◆

or to such other address or transmission receiving station as specified by a party by Notice to the others.

5.8 **Deemed Receipt** - Any Notice delivered or sent by facsimile transmission or other similar form of electronic transmission will be deemed conclusively to have been effectively given on the day Notice was delivered or sent as aforesaid if it was delivered or sent on a day that was a Business Day at the place of the intended recipient or on the next day that is a Business Day at such place if it was delivered or sent on a day that was not a Business Day at such place.

5.9 **Change of Address** - A party may at any time, by Notice to the other, change its address to some no less convenient address and will so change its address whenever its address ceases to be suitable for delivery by hand.

5.10 **Further Assurances** - Each party will execute and deliver such further agreements and other documents and do such further acts and things as the other party reasonably requests to evidence, carry out or give full force and effect to the intent of this Agreement.

5.11 **Binding Effect** - This Agreement will enure to the benefit of and be binding upon the respective successors and permitted assigns of the parties.

5.12 **Survival** - All rights and obligations of the parties occurring before the effective date of termination of the Software License and all rights and obligations expressly stated to continue after, or accrue as a result of, the termination of the Software License are separate and distinct rights and obligations binding on the parties, will survive its termination and will continue in full force and effect and nothing herein will affect the enforceability of such provisions.

5.13 **No Partnership** - Nothing herein will or will be deemed to create any partnership or joint venture between the parties or to give either party any right or authority to act as the agent of or to pledge the credit of the other party.

5.14 **No Publicity** - Save as required by applicable securities laws or other requirements of applicable Governmental Authorities, neither party will reveal the subject matter of this Agreement in any press release, advertisement or other publicity whatsoever without the prior written consent of the other party.

IN WITNESS WHEREOF the parties have caused this Agreement to be executed by their duy authorized officers as of the day and year first written above.

BALLARD POWER SYSTEMS INC.

By: .________________________________.

Title: .________________________________.

By: .________________________________.

Title: .________________________________.

◆________________________◆

By: ◆________________________________◆

Title: ◆________________________________◆

By: ◆________________________________◆

Title: ◆________________________________◆

SCHEDULE A

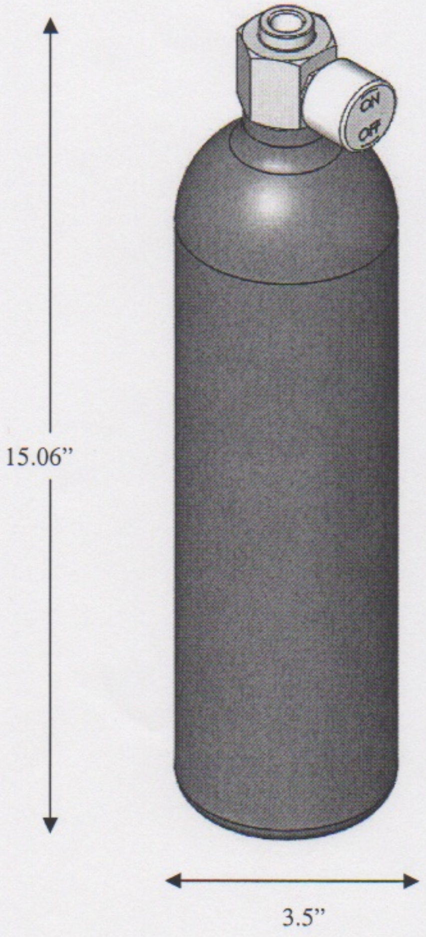
LICENSED PRODUCT

Nexamon OEM Software

PRE-PRODUCTION PROTOTYPE* SPECIFICATION SHEET

OVONIC SOLID HYDROGEN STORAGE CANISTER

MODEL NO. 85G250B-NPT



Dimensions: 8.9 cm O.D., 38.3 cm length
(3.5" O.D., 15.06" length)

Weight: 6.5 kg (14 lbs)

Deliverable hydrogen storage capacity:
80 grams, 900 std. liters (depending on use conditions)

Maximum internal pressure:
250 psi at 25°C

Container: 1800 psi DOT 3-AL cylinder

Connection: 1/8" FNPT with manual shut-off

Safety devices:
Thermal / pressure relief certified to CGA S-1.1 (CG-7 and CG-10)

Storage conditions: -29 to +54°C
(-20 to +130°F)

Operating conditions: 0 to +75°C
(+32 to +167°F)

*PATENT PENDING

Texaco Ovonic Hydrogen Systems LLC
A joint venture company of Energy Conversion Devices and ChevronTexaco

2983 Waterview Drive, Rochester Hills, MI 48309
Tel: (248) 293-8772 Fax: (248) 299-4520
www.txohydrogen.com

OVONIC
HYDROGEN
solutions

September 2004